BW and BW Defence Field Trials Conducted by the UK: 1940-1979 (UC)

DERA/CBD/CR990038 Copy HL of 44

Cover + viii + 60 pages

February 1999

[redacted]

DERA

DERA is an Agency of the UK Ministry of Defence

Record of changes

Issue	Date	Detail of Changes
1.0	February 1999	First Issue

Abstract

This report surveys the BW and BW defence trials conducted by the Porton Establishment and notably MRE and its precursors from 1940-1979. The survey is probably more than 95% complete. It is a largely chronological history and arises from review of a large volume of reports and files. Deficiencies exist in many past records of field trials in the context of modern enquiries. Such deficiencies are now hardly remediable but they could be avoided in the future. A brief rationale for the future recording of CBD Sector field trials is outlined.

Key words: Field trials, BW, BW defence, history, BDP, MRD, MRE, N, W, L, X, UL, US, FP, SM, BG, U, EC, MRE162, SEB, sabotage, detection, simulants, HARNESS, CAULDRON, HESPERUS, OZONE, NEGATION, Gruinard, Penclawdd, Underground, Westwood, GPO, Icing Tanker, Lyme Bay, Dorset, Southampton, Swindon, OAF, KOLANUT, VARAN, DICE, MAPRE, Archive

Executive summary

The trials conducted by the UK from 1940-1979 are collated and summarised for the first time. These have important PR relevance since some, involving the dissemination of aerosols of a fluorescent compound and others involving aerosols of non-pathogenic micro-organisms, often resulted in the exposure of a then unwitting public. Some trials involving the dissemination of pathogenic micro-organisms at three sites in the UK were conducted during W.W.II. Others involved the dissemination of pathogens at sea in Scottish waters and in the West Indies in the 1950s.

Some PR difficulties have arisen latterly because critical data have not always been included in the essentially scientific field trial reports of the past. The ways whereby such deficiencies could be avoided in the reporting of current CBD Sector trials are briefly discussed. The openness and transparency about past activity at Porton encouraged in recent years and the increased availability of Porton reports in the PRO has not diminished Parliamentary and public concern. There is also some impact on non-proliferation concerns.

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1. Introduction

1.1 This is a short account of field trials conducted on the Porton Range, or elsewhere by either of the onetime major Porton Establishments in the context of biological warfare (BW) or biological defence and involving the dissemination of aerosols of agents or simulants into the open air. It is not always possible to decide whether some trials were conducted exclusively by the one Establishment, but generally most trials can be primarily assigned on the basis of initiation and the subsequent level of effort.

1.2 The trials described cover the period 1940-1979. During this period both Porton Establishments underwent changes of name and the chronology of such changes in two Establishments may cause confusion. The senior Porton Establishment (now the CBD Sector) started at Porton in 1916 and was the home of both chemical warfare (CW) and chemical defence until about 1956, continuing thereafter to deal exclusively with chemical defence and later, in 1979, to embrace biological defence, upon the closure of the Microbiological Research Establishment (MRE). MRE had evolved from the highly secret autonomous unit Biology Department, Porton (BDP), started in 1940 and lodged within what was then the Chemical Defence Experimental Station (CDES) at Porton. In 1946, BDP became the Microbiological Research Department (MRD). This title continued to 1956, despite the removal of MRD to a new building a mile from what had by now become the Chemical Defence Experimental Establishment (CDEE). In 1956 MRD was renamed MRE and retained this title until its 1979 closure as an MOD Establishment. What had been MRE then entered the Public Health Laboratory Service (PHLS) with the new title of Centre for Applied Microbiology and Research (CAMR). Later, CAMR left the PHLS and in 1994 became a Special Health Authority, an independent Public Sector body, reporting to the Department of Health, under the Microbiological Research Authority (MRA).

1.3 The complexities of changes of title at Porton are such that it is worth setting them out here.

1.3.1 Titles for the chemical warfare[1] or chemical defence area

- War Department Experimental Ground	1916
- Royal Engineers Experimental Station	1916-1929[2]
- Chemical Warfare Experimental Station (CWES)	1929-1930[2]
- Chemical Defence Experimental Station (CDES)	1930-1948[2]
- Chemical Defence Experimental Establishment (CDEE)	1948-1970
- Chemical Defence Establishment (CDE)	1970-1991
- Chemical and Biological Defence Establishment (CBDE)	1991-1995
Chemical and Biological Defence Sector of DERA	1995-present

[1] Since the late 1950s Porton has been solely concerned with the provision of effective defensive measures.
[2] In such times many official papers used merely the title. 'The Experimental Station, Porton'.

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1.3.2 Titles for the biological warfare[3] or biological defence areas

- Biology Department, Porton (BDP) 1940-1946[4]
- Microbiological Research Department (MRD) 1946-1957[5]
- Microbiological Research Establishment (MRE) 1957-1979[6]

In 1979, when MRE closed, CDE became responsible for both chemical and biological defence and in 1991 changed to CBDE to reflect its new role. This continues in its CBD Sector title.

1.4 What constitutes a "field trial" or "trial"? These terms embrace diverse activity. However, for the purposes of this report, largely only those field trials in which BW agents or simulants were disseminated as aerosols into the ambient air (whether in the open or in public areas) will be considered. Some information is also provided on trials involving the exposure of microthreads charged with microbial aerosols in the outside air, though generally this work is not associated with al fresco dissemination. The account finishes in March 1979 when MRE closed.

1.5 Perception of past field trials is largely dependent on the existence, survival and identification of a written record. In most cases these have existed, survived and have been identified. The records are not as detailed as they might have been. This reflects the practices of yesteryear, when no one could have foreseen the levels of interest and concern which arose in recent times. A lack of precision often exists and it is not always possible to know the location of all trials, the dates and times, the volume, concentration and dissemination periods of aerosolised materials. Whilst most trials will have had a formal trials programme document, these have not always survived. Further, there is a traditional dichotomy between the number of trials programmes and the number of trials reports. Unsuccessful trials or minor trials may have no surviving report. For some such trials a vestigial record may have existed in some other form e.g. laboratory note book or some informal running list of trials but very few such records have survived. No reason would have been seen for such retention in earlier times. However, there are formal field trials reports for most BW-related trials, which generally give a reasonably useful account. The present survey has probably achieved more than a 95% complete account.

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3 See footnote 1.

4 Located within the then CDES but as an autonomous unit.

5 Located initially within CDES as described above (4) but from 1951 as a geographically separate Establishment within a mile of CDES.

6 Merely a change of title.

1.6 CW and BW are almost unique military topics because they have little obsolescence. Data derived in W.W.I about the military utility of mustard gas or that got in W.W.II on the dissemination of anthrax spores may be equally relevant to current situations. The significance of non-proliferation efforts in these fields cannot be under-emphasised but must be considered in the context of what already exists in the public domain.

2. Simulants

2.1 Many of the field trials described in this report were conducted with simulants rather than with BW agents. The rationale is obvious: it is generally more convenient to use a harmless chemical compound which mimics the physical characteristics of a BW agent aerosol particle, for some types of large area trial. For other types of trial where the biological decay rates of microorganisms contained in an airborne particle is all-important, then a harmless microorganism which is known to behave much like some specific BW agent may be used. Ultimately, data from trials with simulants may need to be substantiated by trials with agents. However, no field trials which involved the dissemination of BW agents in the open air have been done by the UK since Operation NEGATION in 1955, where under safe conditions at sea four pathogenic microorganisms were disseminated by spraying.

2.2 The ideal simulant would show every one of the characteristics of its mirrored BW agent except its pathogenicity or toxicity i.e. it would not cause infection or intoxication in man and the natural fauna. In all other respects, it would have the same physical, biochemical and immunological characteristics. This ideal simulant does not of course exist and each of the simulants selected for UK work differed from BW agents in several respects. Nevertheless, the use of simulants provided critical data relevant to both BW and BW defence. Only one simulant utilised by the UK was a chemical compound i.e. FP, used to simulate the aerosol particle per se, rather than the BW agent contained within aerosol particles. These simulants are now dealt with in turn.

2.3 Zinc cadmium sulphide (FP)

This was known locally as "fluorescent particles" "fluorescent pigment" or "fluorescent-powder" (FP) and was a fluorescent pigment NJZ 2266 from the New Jersey Zinc Co and generally described as a dry powder particulate of circa 0.5-3 mμ diameter: 1 gram contained circa 10^{10} particles. Later a Type 2267 from the US Radium Corporation was used, after being magnesium silicate-treated by CDE Nancekuke (to improve its flow in dissemination). FP was apparently first used on the Porton Range. Later, field trials to establish the feasibility of covering tens of thousands of square miles of the UK with an aerosol were done. The assessment of coverage was mainly by the microscopic counting of impacted spots on exposed sampler paper, visualisation being by ultra-violet light. In some trials liquid-filled impingers were also used i.e. the aerosol was collected in a fluid.

The meteorological use of FP was probably first cited as early as 1952 in the Proceedings of the Second National Air Pollution Symposium, in California, and as having been used for about the four previous years . The definitive book "Particulate Clouds: Dusts, Smokes and Mists" of 1957 refers to both UK, US and Australia meteorological use of FP, especially in cloud-seeding (rain making). The authoritative 1969 UN publication "Chemical and Bacteriological (Biological) Weapons and the Effects of their Possible Use" produced by a multinational group of consultant experts refers to FP as "a harmless powder".

2.4 Zinc occurs widely in nature and is a nutritional trace element. Cadmium is generally less abundant but zinc and cadmium are frequently in association e.g. in zinc ores. FP a recognised air movement tracer in meteorology, was widely used in many nations. A 1979 note suggests that an individual exposed out of doors within trial areas during all the FP field trials conducted by CDE could have inhaled 1 µg, which could, in the light of published natural intakes of both elements, be seen as a wholly trivial exposure in relation to the known toxicity. Nothing appears to have arisen since 1979 to change this view. A panel of the National Academy of Sciences reviewed the occasions in the 1950s and 1960s when FP had been disseminated by the US. In May 1997 the reviewers concluded, ' After an exhaustive, independent review requested by Congress we have found no evidence that exposure to zinc cadmium sulphide at these levels could cause people to become sick.' and ' Even when we assume worst about how this chemcial might behave in the lungs, we conclude that people would be at a higher risk simply from living in a typical urban, industralised area for several days or, in some cases, for months.'

2.5 Serratia marcescens (SM)

This bacterium is one of the genera which comprise the Enterobacteriaceae family. The taxonomy of this enteric group is complex and ever changing. SM was first described in 1823 and for years termed Bacillus or Micrococcus prodigiosum before being inserted into the genus Chromobacterium as Chromobacterium prodigiosum, re-classified later as Serratia marcescens. It is widely distributed in nature and though, like most non-pathogens, it is generally regarded as harmless, there are several scattered accounts of association with human disease. SM is a useful tracer because many strains have a pigment, which when colonies are grown on solid media, enables those colonies to be distinguished from other incidental contaminating bacterial colonies. It is difficult to determine when SM was first aerosolised in UK field trials. SM was certainly available at BDP and indeed used as a convenient simulant in some experiments on flies as disease vectors but these involved no aerosolisation of SM. It was also used in work on the preservation of viability and virulence. The major field trial use describes the strain of Bacillus prodigiosum as obtained from the National Collection of Type Cultures and as "a harmless microbe". It was aerosolised from 4 lb bombs on the Porton Range to evaluate the possibilities of using non sporing bacteria in BW. Whilst SM behaved satisfactorily in laboratory aerosolisation by spray, the heat and shearing effects of a bomb functioning produced great destruction. Whilst this did not preclude the BW utility of non-sporing bacteria, it led to little further W W II field work with such bacteria, beyond three trials on the Porton Range with SM in the 4 lb bomb.

2.6 SM continued to be occasionally used at Porton up to circa 1977 i.e. just before the closure of MRE. Generally, when assessment of viability was not an issue, the SM was "killed" by the addition of phenol. Invariably, on such occasions it was mixed with BG spores, which being resistant to the low concentration of phenol, remained viable and provided a useful tracer. It appears likely that, apart from field trials on the Porton Range, all the use of SM in public areas and at sea has been with phenol-inactivated SM.

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2.7 Bacillus globigii (BG)

This bacterium, of the Bacillaceae family, is ubiquitous in nature and is readily cultured from hay, dust, water etc. It is regarded as a non-pathogen. There has been little suggestion of infection in man or animals following inhalation of BG spores, even in massive doses. Note that like Bacillus anthracis, BW-related field trial usage is solely with the spores and not the vegetative bacilli. Originally, during W.W.II at BDP, this bacterium, isolated from animal house hay in 1940, was known as Bacillus subtilis and code-named originally but briefly S, but later U or Porton U. Great confusion has prevailed about BG and U but it is generally regarded that they are synonymous. Later, largely due to taxonomic changes, the Porton usage of U, changed to BG. Various strains of BG e.g. B. subtilis var niger have the ability to produce pigmented colonies after culture on solid media. This is a valuable convenience in identifying and counting specific colonies in both quantitative and qualitative assays. Later, most of the BG used was of US origin and known locally as "shoe string" BG. Few reports identify when the designation U was discarded in favour of BG but for all practical purposes they can be regarded as synonymous. There was never any inhibition about BG: it had been widely used as a tracer in both aerobiological work and in the water industry. During W.W.II BG was the ideal simulant for the spores of Bacillus anthracis (code-name N). N spores were the principal BW agent worked on at BDP. Later, it was apparent that U or BG were an admirably stable tracer for many types of aerobiological work, both in the laboratory and the field. U or BG were therefore sometimes added in small proportions to the suspensions of SM or Escherichia coli (EC) or pathogens disseminated in trials, providing a highly stable tracer for the other relatively unstable simulant. The proportion of BG to SM or EC in the original suspension being known, any loss of viability i.e. death during aerial passage would be indicated by the relative fall in the numbers of the main element of the mixture i.e. SM or EC. Further the rate and extent of the loss of viability could be quantified.

2.8 In the US, the Surgeon General indicated in 1970 that there is no evidence of infection in man or animals following exposure to BG, even in massive doses. No aerosolisation in public places or at sea seems to have been carried out by the UK since 1977 but BG continues to be used in small trials on the Porton Range.

2.9 Klebsiella aerogenes (KA)

This was earlier known as Bacterium, then Bacillus, then Aerobacter and currently K. aerogenes and is well established as a harmless, ubiquitous saprophyte and commensal. Its main field trial use in the UK appears to have been when killed and stained with primulin or methylene blue, so that the sampled aerosol particles could be visualised by microscopy. Primulin-staining produced fluorescence which was particularly sensitive to ultraviolet microscopes. K. aerogenes has attracted little attention as a simulant. Klebsiella species have been associated with opportunistic infections, notably in hospitals. KA is merely an abbreviation for this report.

2.10 Bacillus pumilis spores

This is another harmless ubiquitous saprophyte. Its main UK use was in the 1953-1954 trials on the vulnerability of railway carriages to BW attack. The rationale for its use seems solely to be the avoidance of misleading contamination from earlier use of BG in the same railway carriages.

2.11 Bacteriophages

The simulation of viruses is more difficult than that of bacteria: the reasons need not be dealt with here. On the occasion when MRE simulated the BW use of viral agents, it used a bacteriophage or phage. Phages are bacterial viruses i.e. viruses which can only infect bacteria and which are quite harmless to man. They are, in reality, poor simulants of viruses which cause human infectious diseases. Coliphages are those phages specific to coliform bacteria such as E. coli. The coliphages T1 and T7 were aerosolised occasionally on the Porton Range and used in microthread experiments at sea, when survival in ship machinery spaces was compared with survival outside. In the context of this report, the only significant use was in May 1964 when a mixture of dried BG and T1 was aerosolised after release from a small cardboard box dropped from a moving London Underground train (see Section 7).

2.12 Coliphages are ubiquitous in faeces, from which they may be isolated. Therapy for bacterial diseases by the introduction of phages into patients was a once much vaunted concept for destroying invasive bacteria. For several reasons, this concept never took off in the western world, though it still is something of a vogue in the former USSR. There is absolutely no suggestion of phages posing any hazard to man.

2.13 Escherichia coli strain MRE 162 (EC)

EC is a commensal bacterium and the largest part of the normal flora of the human and animal intestine. Faeces may contain as much as 10^9 EC/gram. Within the gut, EC is generally harmless; if it reaches other internal organs it maybe pathogenic. Even within the gut, strains may arise which cause a variety of gastro-enteric conditions. The isolation of such strains is a major aspect of medical microbiology. Traditionally, EC was especially implicated in acute diarrhoea in childhood but in recent years it has been increasingly responsible for serious outbreaks of "E. coli food poisoning" and deaths in adults. However, many EC strains are quite harmless.

2.14 EC MRE 162 was isolated from a lavatory bowl in MRD in 1949, designated No 162 in the MRD Culture Collection and was subsequently used in MRD/MRE for many years. In 1961, since inadvertent exposure of the public would arise in proposed trials where the volume of releases would be substantially larger than in most earlier field trials, the approval of BRAB (Biological Research Advisory Board) was obtained by Dr D W W Henderson, then D/MRE. This approval was subject to full checks of the harmlessness of simulants, a condition which was rigorously adhered to. By August 1969, 41 batches of EC had been tested: only two were rejected when the possible presence of intercurrent disease in test animals prevent any valid conclusions. In August 1969 BRAB was asked for specific approval for the field use of EC. The 1961 approval had been for "living non-

pathogens". The 1969 request was specific to EC and its emergence was undoubtedly due to an increasingly stringent MRE attitude, and almost certainly influenced by the new D/MRE's medical background. BRAB approval was received. Documents of the period record that tests repeated on each Pilot Plant batch measured virulence, drug sensitivity, serological reactions, uptake of labeled antibody, purity, biochemical reactions, viability and aerosol stability. The virulence tests involved intraperitoneal injection of mice with doses up to and including 10^7 bacteria and exposure to inhalation doses of 10^5 bacteria. Histological study of mice seven days after inhalation failed to show any pathology. It was concluded that all reasonable precautions had been taken to ensure the safety of EC.

2.15 The last use of EC on the Porton Range, albeit within 62 m^3 portacabins, was probably with BG as a tracer, circa 1977. The last release elsewhere was probably at sea off Portland in 1970, when a frigate was challenged.

3. Agents

3.1 No more detail is provided here than to list the agents used, where and when this occurred, any W.W.II code-names and the disease associated with the agent. Further reading on these agents, which are except for the toxins, all ordinary pathogens of man and animals, may be got from any text on medical microbiology. The list is basically chronological: some duplication occurs.

Date	Location	Agent	Code	Disease name
1941-1942	Porton Range	*Ricin	W	
1942	Gruinard Island	B. anthracis	N	Anthrax
1942	Penclawdd	B. anthracis	N	Anthrax
1943	Gruinard Island	B. anthracis	N	Anthrax
1944	Porton Range	**Y. pestis	L	Plague

Date	Operation	Location	Agent	Code	Disease name
1948-1949	Op HARNESS	Off the Leeward Islands	B. anthracis	N	Anthrax
1948-1949		Off the Leeward Islands	***Brucella suis	US	Brucellosis
		Off the Leeward Islands	***Brucella abortus		Brucellosis
1948-1949		Off the Leeward Islands	Francisella tularensis	UK	Tularemia
1952	Op CAULDRON	Scottish waters	Y. pestis	L	Plague
		Scottish waters	***Brucella suis	UL	
1953	Op HESPERUS	Scottish waters	***Brucella suis	US	
		Scottish waters	Francisella tularensis	UL	
1954	Op OZONE	Caribbean waters	***Brucella suis	US	
			Francisella tularensis	UL	
			****Venezuelan Equine Encephalomyelitis Virus	NU	
1955	Op NEGATION	Caribbean waters	***Brucella suis	UL	
			Francisella tularensis	UL	
			*****Vaccinia virus	AC	

* *Originally this was regarded as a putative CW agent. By modern standards, the BWC and the CWC, it is both a CW and BW agent.*

** *This was an avirulent strain of Y. pestis described as "of Otten" used as a simulant of a virulent strain. It would not now be described as a simulant proper.*

*** *These several Brucella species evoke diseases with distinct names in man and certain animal species but Brucellosis is a good empirical term. Note that Brucella abortus is described as a simulant in Operation HARNESS but would not now be so regarded.*

**** *This virus and the disease are synonymous.*

***** *Not a simulant proper but a mild pathogen and the source of smallpox vaccine, this was used to simulate smallpox virus, its near relative.*

3.2 The use of the term "simulant" for the 1944 field trial use of avirulent Y. pestis, the 1948-1949 use of Brucella abortus and the 1955 use of vaccinia virus to simulate smallpox virus, is a different sense of the term. In these instances there was clear simulation but the plague bacterium, the Brucella species and the vaccinia virus used are,

for different reasons, not in the same category as the microorganisms described in Section 2. Whilst the avirulent Y. pestis was attenuated to the point where it failed to kill laboratory animals, it remained essentially the causative organism of plague. The A19 strain of Br. abortus was described variously as "avirulent" or "of low virulence". Whilst vaccinia virus was in international use in vaccination against smallpox, it remained a low grade pathogen and could occasionally but rarely in nature result in local and systemic infections amongst both those vaccinated and the careless vaccinator.

3.3 Botulinum toxin (X)

This toxin, produced by the bacterium Clostridium botulinum, is of limited relevance since its only known field trial use was in the W.W.II testing of ad hoc grenades on the Porton Range (see para 14.3). No aerosol dissemination was involved: botulinum toxin was never aerosolised in the field by the UK. X is a W.W.II codename, which continued to be used informally for some years after the war.

3.4 Staphylococcus enterotoxin B (SEB)

This BW agent, a toxin produced by the bacterium Staphylococcus aureus, is of limited relevance since its "field" use appears to have been limited to trials in 1973 when microthreads charged under fully contained conditions within MRE were exposed to the air passing through a fully contained safety cabinet on the roof of MRE. Thus, there was no al fresco dissemination or unprotected exposure of SEB in this work (see para 10.10). SEB is an abbreviation, not a codename.

3.5 Brucella abortus and vaccinia virus (AC)

Whilst these were cited originally and used as simulants they are pathogens, albeit of low pathogenicity.

4. Authority and security

4.1 Questions have been asked in the past (and will arise in the future) about who authorised the UK use of the listed simulants and pathogens in field trials. There is a paucity of information about this aspect and often the questions remain unanswered: they cannot be answered unequivocally from Porton's archives. In many instances the authority emerged no higher than from the Chief Superintendent or Director at Porton, although it is certain that such authority emerged over the years with the stated or tacit agreement of one or more bodies; e g the London-based Headquarters, the post-war CDAB and the later Chemical Defence Board (CDB), the BRAB (and their controlling body) the Scientific Advisory Council (SAC) (later the Defence Scientific Advisory Council (DSAC)), the Principal Director of Scientific Research of the MOS and the several sorts of Chief Scientists in the post-MOS period. Further, during W W.II the War Cabinet's BW Sub-Committee chaired by the Minister without Portfolio or the Chancellor of the Duchy of Lancaster would have provided authority emerging from the War Cabinet and thus from Ministers. Essentially, specific authority is almost impossible to trace but knowledge and tacit agreement is often identifiable.

4.2 It is clear, from asides in the main field trial reports and the letter books kept by MRD, that the sea trials of 1948-1955 were dependent on Cabinet or Cabinet Committees and the Ministry of Supply's and COS agreement. For Operation NEGATION, Prime Ministerial approval was cited. The W.W.II field trials with anthrax on Gruinard Island and at Penclawdd were authorised at the highest level, at least by Mr Duff Cooper as Chairman of the relevant Committee. The early W.W.II field trials with Ricin on the Porton Range (Section 5) however remain, in this context, obscure. The "sabotage" trials (Section 7) with simulants were certainly known to the MOS hierarchy, BRAB and some to the Post Master General. The remainder of the MRD/MRE trials with simulants of the 1960s and 1970s were also known to BRAB and the ministerial hierarchy of MOD and the Services. The COS Committee BW Sub-Committee, the Inter Services Sub-Committee on BW and the Defence Research Policy Committee were also important in this context in the earlier post war period.

4.3 Generally speaking the only identified authority is for approval of the use of live non pathogenic simulants in the field. This is the 1961 BRAB approval for such use in trials which might involve exposure of members of the public (apparently an approval for the use of any living non pathogen, subject to rigorous testing of every batch in animals, although clearly EC was the prime issue) and the 1969 BRAB approval, subject to the same rigorous testing, but specifically for EC. The use of FP appears not to have required any specific authorisation since it was in international meteorological use.

4.4 Tacit approval for simulant trials where the public might be exposed was strongly influenced by defence security considerations aimed obviously at restricting public knowledge. An important corollary to this was the need to avoid public alarm and disquiet about the vulnerability of the civil population to BW attack. This is particularly apparent in discussions and correspondence about field trials in the London Underground and arose again later with the Lyme Bay trials (Section 9). Further, during the latter, the presence of USSR fishing vessels (with intelligence-gathering equipment), the extensive

Authority and security

use of radio communication and the use of Land-Rover sampling vehicles in the Dorset countryside at night presented security problems. As in the FP trials, a cover story about meteorological and air pollution work was readily constructed for any inquisitive enquirer. Both aspects were of course not incorrect.

4.5 The matter of authority is now almost impossible to retrace. However, all use of simulants and agents was approved by some official or a body in authority and more importantly, it is clear that appropriate bodies such as the CDAB, CDB and BRAB with extensive independent membership, had knowledge of the range of field trial work. Further, the eminence of these independent members and their Chairman need hardly be stated. All such bodies were particularly strong in their medical membership.

5. World War II field trials: 1941-1945

5.1 Ricin (W): Porton Range: 1941-1942

5.1.1 Ricin is a potent toxin readily extractable from the seeds of the castor oil plant (Ricinus communis). In recent times it became well known because of its use in the assassination of the Bulgarian emigré Georgi Markov in London in 1978. Because ricin was of botanical rather than microbial origin, W.W.II research at Porton was by the then CDES, rather than BDP. Notwithstanding, all toxins of whatever natural origin, eventually became generally regarded as BW agents and were included in the 1972 Biological Weapons Convention (BWC). However, toxins were also included in the 1993 Chemical Weapons Convention (CWC), since they were intrinsically "non-living" and thus CW agents. Inclusion in both conventions ensures that arms control becomes more effective. It is not apparent why ricin was studied by CDES but laboratory research in its Physiological Section soon demonstrated that animals were susceptible to it by injection, ingestion and inhalation of aerosols. Further, its toxicity was high. This led to field trials on the Porton Range when bombs charged with ricin were exploded on the ground up wind of an arc of animals and sampling devices. The purpose was essential to evaluate the toxin as a possible CW agent. In all, 15 trials were carried out between 12 September 1941 and 31 October 1942.

5.2 Anthrax (N): Gruinard Island and Penclawdd: 1942-1943

5.2.1 Gruinard Island in Gruinard Bay, Ross-shire on the NW coast of Scotland was used for field trials in support of the W.W.II N-bomb programme in 1942 and 1943. The first trial on 15 July 1942 is of historical significance because it was the first UK demonstration of the feasibility of BW under realistic conditions. Whilst the 1942 trials centered on HE/chemical bomb charged with N spores, trials with BG-charged bombs on the Porton Range showed that a 4 lb HE/chemical bomb Type F was more efficient and suitable for development as the sub-munition for a cluster bomb of 106 sub-munitions. In 1943 trials were resumed with the 4 lb bomb, both statically exploded and fired from an inverted mortar, to simulate an aircraft drop. In both 1942 and 1943, the only animals used in the trials were sheep.

5.2.2 A few trials were also done in 1942 to demonstrate that sheep could be killed behind armour sheets by the aerosol created by the break-up of Hispano rounds each containing 1.7 mls of N spore suspension. Such usage (not developed further) was likely to be effective in attacks on AFVs.

5.2.3 A trial when a 30 lb bomb was dropped from a Wellington bomber flying at 7000 feet was unsatisfactory. The bomb struck a peat bog and no sheep died and it was concluded that the major part of the charging had been driven into the ground and an ineffective cloud resulted. A single replacement trial was hurriedly arranged on a military beach range at Penclawdd on the Gower coast in October 1942 when a 30 lb bomb was dropped from a Blenheim bomber flying at 4950 feet above the site. Animals in both the 120 and 320 yard arcs died 3 days later, confirming operational effectiveness and underlining results at Gruinard with static bombs. Unlike the situation at Gruinard Island, the site was swept by the tides each day and no residual contamination of terrain ensued.

World War II field trials: 1941-1945

5.2.4 In August 1943 trials were resumed with the 4 lb bomb to confirm that the same increased efficiency could be obtained with N spores as with BG spores, and to support the recommendation that the 4 lb bomb should be developed as the sub-munition for the clustered N bomb. Results showed that earlier estimates had been conservative: there was no statistical difference between simulant trials and N trials. Further, the extra forces involved in the functioning of a moving bomb did not affect viability or virulence; the correlation between inhaled dose and mortality in sheep was the same, whether the N aerosol was from spray in the laboratories, or in the field from bombs. No further trials were done on the Island but further field trials with BG at the Porton Range explored several practical issues in 1943-1944. Gruinard Island was not large enough for trials with N-charged complete cluster bombs containing sub-munitions, nor was it entirely safe for such a scale of dissemination. It was proposed that the US would produce N in bulk and that the clusters so charged would be trialled in Canada. In the event neither came to pass because of the end of the war: the CANUKUS N-bomb project came to a halt. The residue of these wartime field trials on Gruinard Island remained. N spores could be isolated from its terrain each year for decades after the war. How Gruinard Island was eventually tackled by CDE from 1979 and restored to private use in April 1990 as "fit for habitation by man and beast" after nearly 50 years of denial of access, is now well known. The Gruinard Island saga was not greatly vouchsafed until about 1966 when it was confirmed that the residual hazard was N spores. However, the essentially offensive planning and policy behind the field trials was not made apparent to the public until the early 1990s, although the essentials of the trials were in the public domain in the early 1980s. In 1997, there is little activity at Gruinard and Penclawdd that is not available to the information-seeking member of the public. A great deal of organisational detail has not been preserved and the precise site of the trial on the Penclawdd beach cannot be identified. Note that a 1943 colour film of the Gruinard Island trials exists at CBD Sector: this is a notable historical piece which has been made widely available to the media.

5.3 Yersinia pestis (L): Porton Range: 1944

Towards the end of W.W.II, BDP devoted some time to Yersinia pestis (L), generally the "avirulent strain of Otten" or a virulent strain. By 1944 the susceptibility of mice to aerosols of virulent L had been demonstrated in the laboratory. Then, two field trials were done on the range when the avirulent L was aerosolised from static bombs. The aerosol was sampled at 50 yards. No animals were involved since the L was known to be avirulent.

6. The major sea trials 1948-1955

6.1 After W.W.II it was decided that the concept of using the sea as a safe substrate for pathogen trials should be evaluated. The concept, first mounted in 1944 sprang into life as Operation HARNESS in 1948. The plan was to launch from one ship a string or "trot" of 35 floating rubber dinghies carrying air sampling devices and animals, expose this arc, facing up-wind, to the aerosol of a pathogen released from a static 4 lb bomb or a spray apparatus and then transfer the "trot" to a second "dirty" ship for assessment of results. The "trot" gear was then sterilised and returned to the first ship and the cycle repeated as required. The trials were to be done on the open sea but a land base for normal and infected animals was established on a former US seaplane tending base on the north coast of Antigua, part of the Leeward Islands. Ultimately the HARNESS trials were done in calm waters in the lee of St Kitts, off Basseterre and about a mile off shore. We can now look at the five Operations on an individual basis. Note that in each of the Operations described there were also trials conducted with some of the simulants described in Section 2.

6.2 Operation HARNESS: 1948-1949

6.2.1 Site

One mile off-shore off Basseterre, St Kitts, Leeward Islands but trials with Brucella abortus and BG were in Parham Bay.

6.2.2 Purpose

Essentially, to develop a technique for the conduct of BW trials at sea. Secondarily, to augment W.W.II data on N, on US and on UL (data for the latter two were solely US-derived).

6.2.3 Means of dissemination

a. the 4 lb bomb as used on Gruinard Island;

b. an experimental spraying device, designed to avoid the effects of explosive forces.

6.2.4 Agent strain details

a.	N	Bacillus anthracis
	Strain:	Vollum (a) a monkey passage strain and (b) a sheep passage strain.
b.	US	Brucella suis
	Strain:	PS III.
c.	-	Brucella abortus (identified in the Operation report as relatively harmless and used here as a simulant for US)

Strain: A.19.

d. UL Francisella tolerance (termed Pasteurella tularense in the Operation report)

Strain: Schu.

6.2.5 Ranges for animals and sampling equipment

50 and/or 100 yards.

6.2.6 Number of trials with each agent, with dates and type of dissemination

	Number of trials*	Dates	Type of dissemination
a. **Simulants**			
- Brucella abortus	5	9 December 1948	Spray
(A.19)	1	11 December 1948	Spray
- BG		16 December 1948	Spray
		16 December 1948	Spray
b. **Agents**			
- N	5	26 January 1948	Bomb
		27 January 1948	Spray
		5 February 1948	Bomb
		5 February 1948	Bomb
		6 February 1948	Spray
- UL	7	9 December 1948	Spray
		9 December 1948	Spray
		11 December 1948	Spray
		11 December 1948	Spray
		16 December 1948	Spray
- US	9	21 December 1948	Spray
		22 December 1948	Spray
		7 January 1949	Spray
		9 January 1949	Spray
		9 January 1949	Spray
		22 February 1949	Bomb
		22 February 1949	Bomb
		22 February 1949	Bomb

* *Note that two or more trials were held on same days.*

6.2.7 Animals used

Sheep, Rhesus monkeys and guinea pigs were the main species used although not all species were used in all trials.

6.3 The main conclusions of Operation HARNESS were:

a. The technique as developed was over complicated.

b. The principle of trials at sea should not however be abandoned; the micrometeorological conditions were ideal.

c. Valuable developments resulted.

d. The results emphasised the marked difference in toxicity between CW and BW.

e. Difficulties in efficient dissemination have again been clearly demonstrated.

6.4 The size of Operation HARNESS can be glimpsed by the total number of 475 civilians and servicemen involved. Of the cost of the Operation, no record appears to survive in the MRE archive.

6.5 Operation CAULDRON: 1952

It was evident that the HARNESS concept of a mobile layout of animals and sampling devices on the sea surface was unsatisfactory. In Operation CAULDRON the concept of a "floating island" was initiated and proved so successful that it was used in all of the successive sea trials with pathogens. The "floating island" was a 200 x 60 ft steel "spud" pontoon, pierhead component of the W.W.II Mulberry harbour equipment, fitted out internally with "clean" and "dirty" compartments for equipment, disinfectant, animals and changing rooms. HMS BEN LOMOND had been extensively refitted and extended. No shore site was available, as in Operation HARNESS. It had been decided (why and by whom remains unrevealed) that the Operation was to be confined to home waters at a bay on the eastern coast of Lewis, Scotland. HMS BEN LOMOND was anchored in-shore and the pontoon moored in the middle of the bay, a mile from HMS BEN LOMOND and half a mile off-shore. Trials with agents aerosolised from bomb or spray on a 25 ft boom jutting beyond the pontoon were done in off-shore winds between SW and NW. Animals and samples were held in a 25 yard arc from the source. Clear range duties were performed by an RN tug HMS HENGIST. The number of civilian and Service personnel was smaller than that for Operation HARNESS. It seems that 158 personnel were involved, in contrast to the 475 people in the earlier Operation. Some 45 short-term visitors attended for 2-5 nights during the trial.

6.5.1 Site

Half a mile off-shore near Tulsta Head and Cellar Head on the north-east tip of Lewis. The use of this site was cleared by the Secretary of State for Scotland.

6.5.2 Purposes

6.5.2.1 The essential purposes of Operation CAULDRON were:

a. To test techniques using the pontoon.

b. To increase data on US effectiveness when aerosolised from bombs.

c. To evaluate the effectiveness of virulent L in the field.

6.5.3 Means of dissemination

a. The B/E 1 and B/E 2 bombs.

b. The Collision spray device.

6.5.4 Agent strain details

a. L Yersinia pestis

Strain (i) Avirulent Soemedang strain

(ii) Virulent 337 strain.

b. US Brucella suis

Strain PS III K strain.

c. Note that SM mixed with Bacillus pumilus AS11 strain spores and also Bacillus pumilus AS11 spores alone were used in a few working-up trials and in 10 "long range" trials.

6.5.5 Ranges for animals and sampling equipment

a. Mainly 25 yards i.e. restricted by the length available on the pontoon.

b. "Long range" trials with simulants, at half mile, two miles and three miles between bomb and pontoon. The bombs were carried on a float towed into position.

6.5.6 Number of trials with each agent, or simulant, with dates and type of dissemination

	Agent/Simulant		Date	Dissemination method
L	Avirulent Soemedang	)	26 May	Bomb
L	Avirulent Soemedang	)	6 June	Bomb
L	Avirulent Soemedang	)	6 June	Bomb
L	Avirulent Soemedang	Pontoon)	8 June	Spray
L	Avirulent Soemedang	)	8 June	Spray
L	Avirulent Soemedang	)	11 June	Bomb
L	Avirulent Soemedang	)	11 June	Bomb

Agent/Simulant		Date	Dissemination method
	)		
AS11	)	12 June	Bomb
AS11	)	12 June	Bomb
AS11	)	24 June	Bomb
AS11	)	24 June	Bomb
AS11	)	1 August	Bomb
AS11	Long distance) trials)	5 August	Bomb
AS11	)	14 September	Bomb
AS11	)	16 September	Bomb
L 337		21 June	Bomb
L 337		21 June	Bomb
US		23 June	Spray
US		23 June	Spray
US		23 June	Spray
US		23 June	Spray
US		2 July	Bomb
US		2 July	Bomb
US		2 July	Bomb
US		26 July	Bomb
US		26 July	Bomb
US		21 August - 3 each day	Bomb
US		22 August - 3 each day	Bomb
US		25 August	Bomb
US		25 August	Bomb
US		25 August	Bomb
L		8 September	Bomb
L		8 September	Bomb
L		8 September	Bomb

6.5.7 Animals used

Guinea-pigs and Rhesus monkeys.

6.6 The main conclusions were:

a. The pontoon technique was excellently suited to the simple, safe and efficient conduct of trials.

b. Good data were obtained for US disseminated from a potential weapon.

c. A technique had been developed for future long range trials.

6.7 Operation HESPERUS: 1953

6.7.1 Site

The major sea trials 1948-1955

1953 saw a return, arising from a Cabinet decision, to the sea site, off Stornaway, Isles of Lewis with the pontoon.

6.7.2 Purpose

The essentials were to compare the performance of two experimental sub-munition units, the British B/E1 bomb and the US E61 bomb, to add to the data on downwind survival of microbial aerosols, particularly UL and to evaluate the E88 spraying device and the Collison spray.

6.7.3 Means of dissemination

a. the B/E1 experimental unit bomb..

b. the US E61 R4 bomb.

c. the Collison spray;

d. the E88 spray.

6.7.4 Agent strain details

US	Brucella suis		
Strain:	PSIIIK		
UL	Francisella tularense		
Strain Schu:	D variant		
- -	Bacillus pumilus spores	)	
Strain	AS11	)	simulants used as tracers
BG	Bacillus globigii spores	)	

6.7.5 Ranges for animals and sampling equipment

a. 25 yards;

b. "Long range" trials generally up to 1,200 yards.

Data are presented in the report in metres and sometimes yards, and time of passage of the aerosol is recorded in seconds.

6.7.6 Number of trials with each agent or simulant, with dates and type of dissemination

Trial No	Date	Agent/simulant	Means of dissemination	
1	26 May	AS11	B/E1	)
2	26 May	AS11	-	)
3	26 May	AS11	B/E1	) Practice runs
4	27 May	AS11	-	)
5	27 May	AS11	B/E1	)
6	27 May	AS11	B/E1	)
7	6 June	US	B/E1	
8	6 June	US	B/E1	
9	6 June	US	B/E1	
10	10 June	US/AS11	B/E1	
11	10 June	US/AS11	B/E1	
12	10 June	US/AS11	B/E1	
13	19 June	US	E61	
14	19 June	-	-	) Dummy runs
15	19 June	-	-	) Dummy runs
16	25 June	UL	Collison	
17	25 June	UL	Collison	
18	25 June	UL	Collison	
19	26 June	UL/AS11	E61	
20	26 June	UL/AS11	E61	
21	26 June	UL/AS11	E61	
22	3 July	UL	E61	
23		UL	E61	
24		UL	E61	
25	6 July	UL/AS11	B/E1	
26	6 July	UL/AS11	B/E1	
27	6 July	UL/AS11	B/E1	
28	6 July	UL/AS11	B/E1	
29	7 July	UL/AS11	B/E1	
30	7 July	UL/AS11	B/E1	
31	7 July	UL/AS11	B/E1	
32	8 July	US/BG	B/E1	
33	8 July	US/BG	B/E1	
34	8 July	US/BG	B/E1	
35	28 July	US	E61	
36	28 July	US	E61	
37	28 July	US	E61	
38	28 July	US	B/E1	
39	30 July	US/BG	E88	
40	30 July	US/BG	E88	
41	30 July	US/BG	E88	
42	30 July	US/BG	E88	
43	30 July	US/BG	E88	
44	31 July	US/BG	B/E1	
45	31 July	US/BG	B/E1	
46	31 July	US/BG	B/E1	
47	31 July	US/BG	B/E1	
48	2 August	US	E61	
49	2 August	US	B/E1	
50	2 August	US	E61	
51	2 August	US	B/E1	

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Trial No	Date	Agent/simulant	Means of dissemination
52	6 August	US	E61
53	16 August	US/BG	B/E1
54	16 August	US/BG	B/E1
55	18 August	UL/BG	E88
56	18 August	UL/BG	E88
57	18 August	UL/BG	E88
58	18 August	UL/BG	E88
59	19 August	UL/BG	B/E1
60	19 August	UL/BG	B/E1
61	19 August	UL/BG	B/E1
62	19 August	UL/BG	B/E1
63	19 August	UL/BG	B/E1
64	26 August	US	B/E1
65	26 August	US	E61
66	27 August	US/BG	B/E1
67	27 August	US/BG	B/E1
68	27 August	US/BG	B/E1
69	27 August	US/BG	B/E1
70	27 August	US/BG	B/E1
71	28 August	US/BG	B/E1
72	28 August	US/BG	B/E1
73	28 August	US/BG	B/E1
74	28 August	US/BG	B/E1
75	28 August	US/BG	B/E1
76	29 August	US/BG	B/E1
77	29 August	US/BG	B/E1
78	29 August	US/BG	B/E1
79	29 August	US/BG	B/E1
80	29 August	US/BG	B/E1

6.7.7 Animals used

Guinea-pigs and Rhesus Monkeys.

6.8 The main conclusions were:

a. The E61 bomb gave 50% more aerosol than the B/E1 but only ⅓ of the particles were in the desirable small size range.

b. The dissemination of UL in the B/E1 bomb produced inefficient aerosolisation of viable UL.

c. There was a significant difference in the viability of pilot-plant US compared with laboratory-grown US.

d. There was no greater loss of viability at half a mile than at shorter ranges.

6.9 HMS GATESHEAD acted as range-clear vessel. No untoward events were recorded. The total manpower involved in the Operation were 195 RN and associated civilian personnel and 15 people from MRD and CDEE (not all these MRD and CDEE staff were present throughout the trials period). Visitors to Operation HESPERUS included several members *of* BRAB and senior US personnel. Operation HESPERUS appears to have achieved less than was expected, due largely to meteorological disturbances. The Operation report looked forward to the better conditions of a new sea site off the Bahamas for Operation OZONE.

6.10 Operation OZONE: 1954

After Operation CAULDRON in 1952 it was decided by the Prime Minister (Sir Winston Churchill) that whilst Operation HESPERUS should continue at the Scottish sea site, a search should be made for a site with the best possible conditions. A survey was conducted in March 1953 and it was decided that a selected area of the Bahamas was "the best place we could find on the surface of the globe".

6.10.1 Site

Off the island of Green Cay, on the eastern edge of the Tongue of the Ocean, and about 5 miles from shore. The precise coordinates for the moored pontoon were 24° 08' 1 N 77° 12'. 1 W.

6.10.2 Purposes

a. To study the influence of aerosol travel on the viability and virulence of US and UL.

b To undertake preliminary studies of Venezuelan equine encephalitis virus NU.

c. to study the influence of various methods of dissemination.

6.10.3 Means of dissemination

a. B/E1 experimental unit bomb

b. E61 R4 bomb

c. Large output Collison spray.

d. "HARNESS"-type spray.

6.10.4 Agent strain details

US Brucella suis

Strain: PS III K PP-1

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UL Francisella tularense

Strain: Schu

NU Venezuelan equine encephalomyelitis virus

BG Bacillus globigii (simulant)

6.10.5 Ranges for animals and sampling equipment

a. Twenty five yards i.e. limited by the pontoon dimensions.

b. Long ranges. In the trials report the emphasis is now on time of aerosol travel rather than distances i.e. a reflection of wind speed. Times range from 3-5¼ minutes and the distances are quoted in metres, rather than yards, from circa 100-1640 metres i.e. extending to a maximum of circa 0.6 miles.

6.10.6 Number of trials with each agent or simulant, with dates and type of dissemination

Trial No	Date	Agent/simulant	Means of dissemination
1-4	22 February	BG	HARNESS-type spray
5-8	24 February	US	HARNESS-type spray
9-12	27 February	US	HARNESS-type spray
13-16	2 March	US	HARNESS-type spray
17-19	7 March	US	HARNESS-type spray
20-22	8 March	US	HARNESS-type spray
23-27	9 March	US	HARNESS-type spray
28-30	12 March	US	B/E1 bomb for trials 29 and 32
31-33	13 March	US	E6 R4 bomb for trials 28, 30, 31 and 33
34-36	24 March	NU	Collison spray
37-41	26 March	UL	Collison spray
42-45	30 March	UL	Collison spray
46-48	31 March	NU (faulty trials)	Collison spray
49-52	1 April	UL	HARNESS-type spray
53-56	17 April	US	HARNESS-type spray
57-59	26 April	NU	HARNESS-type spray
60-61	27 April	UL	HARNESS-type spray
62-65	2 May	UL	HARNESS-type spray
66-69	3 May	NU	HARNESS-type spray
Trial No	Date	Agent/simulant	Means of dissemination
70-73	8 May	UL	HARNESS-type spray
74-77	9 May	NU	HARNESS-type spray
78-81	10 May	NU	HARNESS-type spray
82-84	17 May	NU	HARNESS-type spray
85-88	23 May	UL	HARNESS-type spray
89-93	29 May	UL	HARNESS-type spray

Note that BG was mixed as a tracer with the agent in a large proportion of trials.

6.10.7 Animals used

Guinea-pigs and mice.

6.11 The main conclusions were not recorded in a distinct way in the Operation's report, as in earlier trials reports but they appear to be as follows:

a. An infective particle of any of the pathogens tested has a half life of circa one minute in daylight, although US was more robust than UL and decay rates varied considerably from day to day.

b. Further vulnerabity data on US and UL were acquired.

c. Valuable progress had been made by the work on NU.

d The way was now clear to study further the very rapid viable decay of aerosols in bright sunlight, by comparing results in conditions of negligible sunlight. Decay was assumed to be due primarily to ultra-violet radiation but it was necessary to quantify this phenomenon.

6.12 Whilst the association of HMS BEN LOMOND with BW trials had been noted by the press in June 1952 during Operation CAULDRON, the Cabinet had decided that the "fact of the trials taking place should be secret". The Colonial Secretary (then Acting Govenor of the Bahamas) recommended a press release, however, no immediate statement was made but due apparently to an article by Chapman Pincher in the "Daily Express" a press release was promulgated on 12 March 1954. (This is not reproduced in the Operation report). The release was extensively commented on by the major newspapers and included references to the Operations in Scottish waters, notably CAULDRON.

6.13 Operation NEGATION: 1954-1955

This was originally called Operation RAVISH. The code name was changed in September 1954: the reason has passed into oblivion. Operation NEGATION continued in the Bahamas and was concerned solely with the survival of pathogen aerosols in long downwind travel ranging from 25 yards to over two miles, so that airborne travel periods of a few seconds to 10-15 minutes were obtained.

6.13.1 Site

As for Operation OZONE.

6.13.2 Purposes

a. To study the influence of factors on US, UL and NU, particularly under low light conditions.

b. To study the behaviour of AC aerosols.

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6.13.3 Means of dissemination

All by spray, described as a simple "two-fluid" spray but it is not clear whether this was identical to either of the sprays used in earlier trials.

6.13.4 Agent strain details

US		-	MRD Batches (2 batches)
			Batch AB1 (described as Pine Bluff Batches 1 and 2).
UL	Strain Schu D	-	Batches 1 and 2 prepared at Camp Detrick.
			Batch L.
NU			Batch prepared at Camp Detrick.
AC			Batch prepared at MRD.

6.13.5 Ranges for animals and sampling equipment

a. Circa 25 yards i.e. limited by the pontoon dimensions.

b. Long range trials 27 m- 3.370 m. Times range from 7 seconds-636 seconds i.e. up to a maximum of 1.3 miles.

6.13.6 Number of trials with each agent or simulant, with dates and type of dissemination

Trial No	Date	Agent/simulant	Dissemination method
1	17 November 1954	BG	All trials used spray
2	17 November 1954	BG	
3	17 November 1954	BG	
4	17 November 1954	BG	
5	18 November 1954	UL	
6	18 November 1954	UL	
7	18 November 1954	UL	
8	18 November 1954	UL	
9	18 November 1954	UL	
10	22 November 1954	UL	
11	22 November 1954	UL	
12	22 November 1954	UL	
13	22 November 1954	UL	
14	27 November 1954	UL	
15	27 November 1954	UL	
16	27 November 1954	UL	
17	27 November 1954	UL	
18	28 November 1954	UL	

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Trial No	Date	Agent/simulant	Dissemination method
19	28 November 1954	UL	
20	28 November 1954	UL	
21	28 November 1954	UL	
22	2 December 1954	UL	
23	2 December 1954	UL	
24	2 December 1954	UL	
25	2 December 1954	UL	
26	9 December 1954	UL	
27	9 December 1954	UL	
28	9 December 1954	UL	
29	9 December 1954	UL	
30	13 December 1954	US	
31	13 December 1954	US	
32	13 December 1954	US	
33	13 December 1954	US	
34	13 December 1954	US	
35	13 December 1954	US	
36	13 December 1954	US	All trials used spray
37	13 December 1954	US	
38	16 December 1954	US	
39	16 December 1954	US	
40	16 December 1954	US	
41	16 December 1954	US	
42	17 December 1954	AC	
43	17 December 1954	AC	
44	17 December 1954	AC	
45	17 December 1954	AC	
46	23 December 1954	AC	
47	23 December 1954	AC	
48	23 December 1954	AC	
49	23 December 1954	AC	
50	29 December 1954	AC	
51	29 December 1954	AC	
52	29 December 1954	AC	
53	29 December 1954	AC	
54	30 December 1954	AC	
55	30 December 1954	AC	
56	30 December 1954	AC	
57	30 December 1954	AC	
58	2 January 1955	US	
59	2 January 1955	US	
60	2 January 1955	US	
61	2 January 1955	US	
62	5 January 1955	US	
63	5 January 1955	US	
64	5 January 1955	US	
65	5 January 1955	US	
66	8 January 1955	AC	
67	8 January 1955	AC	
68	8 January 1955	AC	
69	8 January 1955	AC	

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Trial No	Date	Agent/simulant	Dissemination method
70	1 February 1955	UL	
71	1 February 1955	UL	
72	1 February 1955	UL	
73	1 February 1955	UL	All trials used spray
74	2 February 1955	UL	
75	2 February 1955	UL	
76	2 February 1955	UL	
77	2 February 1955	UL	
78	3 February 1955	UL	
79	3 February 1955	UL	
80	3 February 1955	UL	
81	3 February 1955	UL	
82	7 February 1955	UL	
83	7 February 1955	UL	
84	7 February 1955	UL	
85	7 February 1955	UL	
86	8 February 1955	UL	
87	8 February 1955	UL	
88	8 February 1955	UL	
89	8 February 1955	UL	
90	10 February 1955	UL	
91	10 February 1955	UL	
92	10 February 1955	UL	
93	11 February 1955	NU	
94	11 February 1955	NU	
95	11 February 1955	NU	
96	11 February 1955	NU	
97	15 February 1955	UL	
98	15 February 1955	UL	
99	15 February 1955	UL	
100	15 February 1955	UL	
101	16 February 1955	UL	
102	16 February 1955	UL	
103	16 February 1955	UL	
104	16 February 1955	UL	
105	17 February 1955	UL	
106	17 February 1955	UL	
107	17 February 1955	UL	
108	17 February 1955	UL	
109	22 February 1955	US	
110	22 February 1955	US	All trials used spray
111	22 February 1955	US	
112	22 February 1955	US	
113	24 February 1955	US	
114	24 February 1955	US	
115	24 February 1955	US	
116	24 February 1955	US	
117	26 February 1955	US	
118	26 February 1955	US	
119	27 February 1955	US	
120	27 February 1955	US	

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Trial No	Date	Agent/simulant	Dissemination method
121	27 February 1955	US	
122	27 February 1955	US	
123	28 February 1955	US	
124	28 February 1955	US	
125	28 February 1955	US	
126	28 February 1955	US	
127	1 March 1955	US	
128	1 March 1955	US	
129	1 March 1955	US	
130	1 March 1955	US	
131	2 March 1955	US	
132	2 March 1955	US	
133	2 March 1955	US	
134	2 March 1955	US	
135	10 March 1955	US	
136	10 March 1955	US	
137	10 March 1955	US	
138	16 March 1955	US	
139	16 March 1955	US	
140	16 March 1955	US	
141	16 March 1955	US	
142	17 March 1955	US	
143	17 March 1955	US	
144	17 March 1955	US	
145	18 March 1955	US	All trials used spray
146	18 March 1955	US	
147	18 March 1955	US	
148	18 March 1955	US	
149	20 March 1955	US	
150	20 March 1955	US	
151	20 March 1955	US	
152	20 March 1955	US	
153	22 March 1955	US	
154	24 March 1955	US	
155	24 March 1955	US	
156	24 March 1955	US	
157	26 March 1955	AC	
158	26 March 1955	AC	
159	26 March 1955	AC	
160	26 March 1955	AC	

Note that trials 1-4 involved the use of BG in setting-up trials. In the rest of the trials, BG spores were added to the agent as a tracer

6.13.7 Animals used

Guinea pigs and mice.

6.14 The main conclusion were:

The major sea trials 1948-1955

a. The viable decay of UL was strongly influenced by relative humidity (RH), being higher below 80% RH.

b. US was more robust than UL and showed a relative indifference to RH.

c. Strong UV light was a small influence in accelerating the decay of UL.

d. Strong UV light reduced mean survival time of US.

e. Virus results were scanty but suggested that they were indifferent to RH but rather susceptible to UV.

6.15 By Operation NEGATION UK policy on the development of an offensive BW capability had been abandoned. Whilst it was clear that the solely BW defence role now adopted by the UK ideally needed the continuation of such trials, it was evident that money and resources were not going to be made available. In June 1958 the MOS Chief Scientist informed the Royal Navy that the MOS had no further use for HMS BEN LOMOND. Ultimately the ship was broken up. The decision to abandon trials with pathogens at sea was mainly relevant to new UK policy on BW (and CW), defence economies, the emergence of atomic weapons as the prime deterrent and the abandonment of the retaliation-in-kind policy. It was not, at the time, due to governmental inhibitions about such trials, which had provided a safe means of studying particularly fundamental matters in BW. Operation NEGATION was the last UK trial with pathogen aerosols in the open air.

7. The sabotage trials: 1952-1964

7.1 In 1950 the Chief Superintendent of MRD, instigated a series of trials on the behaviour of bacterial aerosols released within buildings or within means of access to buildings. This followed trials by the Special Operations Division at Camp Detrick to determine the vulnerability of large government buildings, including the Pentagon, to sabotage attacks with BW agents. The UK trials were done in the:

a. British Museum Repository at Westwood Quarry Corsham in Wiltshire.

b. Railway coaches.

c. Railway coaches in tunnels.

d. The Wardroom of HMS DUCHESS.

e The GPO cable tunnel system and associated Government buildings in Whitehall.

f. The London Underground.

The UK trials demonstrated the clear vulnerability of these several locations to clandestine attack.

7.2 The Westwood trials: 1950-1952(?)

The Westwood repository of the British Museum was converted in 1937 and completed in 1942. Its use by the British Museum as a repository for national treasures began at the outbreak of W.W.II. In 1950-1952, the repository was empty but maintained by the MOW with conditioned air of accurately controlled temperature and humidity. Permission for the trials was given by the British Museum Director. No dates are given in the trials report. The trials were conducted by the MRD Safety Section staff. The work was classified as Top Secret, being downgraded to Secret in 1964. The main simulant used was SM: a few trials were also done with BG. Because twice-weekly long exposures to the aerosolised bacteria were involved, full protective clothing and respirator use was adopted. Further, the batches of SM were checked for non-pathogenicity by animals tests. The SM was disseminated by a Collison spray or a spinning top apparatus where larger aerosol particles were needed. A variety of sampling devices were used. The chamber, with a volume of 16,500 cubic feet (the "Carpet Room") was used for the trials. The aerosol was disseminated into the ducting serving the chamber and within the chamber, both in a continuous ventilated state and a recirculated state. Air from the system found its way back to the surface through the entrance tunnel, thus some emission to the outside air occurred. At a later stage the exhaust plenum was fitted with a large filter.

7.3 The railway coach trials: 1953-1954

7.3.1 The first railway coach trial on 1 December 1953 was to study the effects of motion and ventilation on aerosols of BG on a down run and Bacillus pumilus spores on a return run, disseminated from a HARNESS-type spray located in the vestibule of the first of two

restaurant cars included in a special train which ran from Salisbury to Exeter and back at 40 mph. Further trials were done in third class compartmental carriages.

7.3.2 The vulnerability of trains moving through a simulant aerosol created externally in a tunnel was also explored. A single restaurant car containing an array of sampling devices was attached to the rear of a regular train. A HARNESS-type spray containing BG spores was installed within a tunnel at Gillingham on the Salisbury-Exeter line, to direct an aerosol around the train traveling through the tunnel at 25-30 mph. With windows and ventilators closed only about 1/10,000 th of the aerosol cloud actually entered the restaurant car. With windows and ventilators open, the concentration in the restaurant car was increased ten-fold.

7.4 The Wardroom of HMS DUCHESS: 1955

During a 1955 study on the naturally occurring airborne bacteria of naval ships under closed-down conditions, done at the request of the Royal Navy Personnel Research Committee in November 1955, the opportunity was taken to study the vulnerability of a vessel's ventilation system. On three occasions suspension of BG was disseminated from a Collison spray into the ventilation duct within the Wardroom of HMS DUCHESS. Air samples taken in the forward citadel.

7.5 The GPO tunnel trials: 1956

Surveys of intra-tunnel air movements were done on 26, 28 July and 3 August 1955 by a CDEE meteorologist. In the first trial, the permeability of watertight bulkhead doors at the foot of a shaft at Faraday House was tested, where a reversible fan was installed. BG spores were released beyond the bulkhead door. Assays of air samples showed that the doors were readily penetrated. In the second trial, the fan was reversed to draw air away from the shaft. Here a leak of even greater magnitude was found. During the second trial the passage of the aerosol from an area under Horseferry Road to Faraday House was determined. Heavy contamination was found in the Air Ministry, the Colonial Office Citadel and what is now the Treasury. In a third trial spores of Bacillus pumilus were aerosolised to pass along the tunnel area known as "Q Whitehall". This showed extensive contamination of many Whitehall buildings.

7.6 The London Underground trials: 1963-1964

The first trial on 26 July 1963 was preceded by a survey and the provision of data from the LTE section of the Northern line from the Oval to Wimbledon South, embracing 10 stations. Studies showed the normal bacterial flora of the Underground was not likely to interfere; the airborne flora was particularly scanty. The simulant used was BG. It was decided to reflect clandestine types of activity by putting BG in a conventional cardboard face powder carton. This was held together in such a way as it burst when dropped from the window of a train. A little of the original face powder was added to "provide the correct odour" so that no undue interest would have been taken in the post-trial discovery

of the box on the track. The carton was dropped by a LTE trainee engineer, who did not know its real purpose under the supervision of a more senior member of staff, between Collins Wood and Tooting Broadway stations. Parties at both stations collected air samples at intervals and on 29 July and 8 August dust swabs were collected over a wide area of the Underground system. Assays, performed conveniently by MRE in the Laboratory of the Government Chemist revealed that the Underground was highly vulnerable to BW attack.

7.7 The second trial was on 1 May 1964, using procedures similar to the first trial. Here coliphage T1 particles absorbed on to 32 g of talc were mixed with 16 g of dried BG spores. Sampling data showed the same dispersion of the simulant. Some of the aerosol traveled within passing trains as well as solely within the tunnels. Results from the assay of phage were disappointing due to aggregation with the talc.

7.8 Note that the MRE reports which describe the two trials have since been covered extensively in the media. The potential for clandestine BW attacks is considerable and great sensitivity had earlier existed about public knowledge of this potential.

8. The Fluorescent Particle (FP) trials: 1955-1963

8.1 The major way in which the FP trials differ from most of the others described here is that they were conducted by CDEE and not MRD/MRE. The principal motivations appear to be meteorological or the large area coverage concept in BW.#

8.2 From November 1953-April 1955 many trials were done from ground based static or mobile dissemination devices located at a variety of sites either within easy reach of Porton or on the Porton Ranges e.g. Beaulieu, Yatesbury, Blandford, near Frome etc. Sampling was generally done at 25 and 50 or 30 and 80 miles downwind. Latterly, assessments of the vertical distribution of FP in the cloud after sampling by aircraft were done. In 1956 and 1957 field trials were done where a long 250 mile line source of FP was disseminated by a venturi device carried in aircraft with sampling deep inland over large tracts of the UK. It was concluded that the UK was particularly vulnerable to attack by aerosols delivered by aircraft.

8.3 In November 1959 attention turned to dissemination from sea-going vessels. HMS BLACKPOOL on passage from Chatham to Londonderry generated two nocturnal emissions of FP, firstly in the Channel and then in the Irish Sea. Sampling was done at points on the south and west coasts and inland. Sampling points were provided at MOS, Meteorological Office and US Air Force (USAF) sites in England and Wales. An area of sea of some 14400 square miles were covered by the aerosol: the concentration recorded on the downwind coast were such as to demonstrate the feasibility of BW attacks at sea on coastal areas and vast areas of inland UK.

8.4 Thus, FP had been extremely useful in delineating the hazard from the large area coverage concept of BW. Later studies suggested that the FP method was probably subject to some intrinsic error due to the decay of fluorescence in a proportion of aerosolised particles during daylight. As a means of delineating the dimensions of an aerosol in time and space FP techniques remained invaluable but uncertainties about concentration distributions within clouds generated in daylight might arise. This did not diminish the significance of the demonstrated vulnerability of the UK but gradually led to the universal discarding of FP in favour of other tracers. Gradually FP work ceased at Porton, as it did in international meteorological research and in BW research. In any event, it had demonstrated the utility of the large area coverage concept. It now fell to MRE to validate the concept by the use of living bacteria.

9. The large area coverage trials by MRE: 1961-1968

9.1 The FP field trials conducted by CDEE had led to the Large Area Coverage BW concept. This was probably first mooted in 1957, although there is some likelihood of a slightly earlier origin. Clearly, new strategic potential for massive clandestine off-target attacks had been displayed by the FP field trials and it was now necessary for MRE to develop trials in which more realistic simulants i.e. live non-pathogenic bacteria were used. Whilst trials with pathogens on the scale of the FP trials, would have been the ideal recourse, such large-scale dissemination of pathogens on land or at sea was unlikely to be contemplated, because of the abandonment of earlier offensive policy.

9.2 Aircraft spray trials: October 1959 and June 1960

9.2.1 In 1957, the National Gas Turbine Establishment (NGTE) was asked by the Chief Scientist MOS to collaborate with MRE in the design of an aircraft spray system to give a worthwhile concentration of bacterial aerosols over long distances downwind. To achieve this and yield microscopic aerosol particles in the lung retention size range was a novel and formidable problem. The first trial at the Balloon Development Establishment (BDE) Cardington in October 1959 involved the NGTE Canberra spraying, through four double impact devices, killed (with formaldehyde and heat) and dyed (with methylene blue) Klebsiella aerogenes (then known as Bacillus aerogenes) at 2000 ft and 410 knots along a track 90° to the wind at one mile from a moored balloon at 2500 ft, which carried six sampling points at vertical intervals on its cable. This trial was a complete sampling failure. The successive trials series were as listed below.

Location and Trial No	Date	Spray devices tested	Average plane distance from samplers (yds)	Number of spraying passes by aircraft
Porton Range 1*	26 Oct 59	4 Double impact	1000	)
Porton Range 2	29 Oct 59	"	1500	)
Porton Range 3	2 Nov 59	"	-	)
Odiham 1**	26 Nov 59	4 Large atomisers	150	) not
Odiham 2	26 Nov 59	"	150	) reported
Odiham 3	30 Dec 59	4 Double impact	150	)
Odiham 4	5 Jan 60	"	160	)
Odiham 5	22 Mar 60	"	190-420	)
Odiham 6	4 Apr 60	4 Large atomisers	147	12
Odiham 7	29 Apr 60	2 NGTE nozzles	120	10
Odiham 8	4 May 60	US Rake	218	15
Odiham 9	23 May 60	2 NGTE nozzles	170	10
Odiham 10	25 May 60	4 Double impact	160	9
Porton Range 4	20 Jun 60	"	170	7
Porton Range 5	29 Jun 60	US Rake	170	10

* *Sampling stations were erected on the 100 ft tower below OP7 or a temporary tower near OP4.*

** *RAF Odiham was, at the time, a non-operational airfield.*

9.2.2 The trials up to that of 22 March 1960 were not regarded as particularly successful in respect of the spraying devices tested. Assay of the sampled bacterial aerosol on slides by microscopy depended on the colouration by methylene blue. However, some fading

effects led to the use of bacteria stained with the fluorescent dye primulin and recourse to ultra-violet light illumination for the microscopes. In the last two trials (Porton 4 and Porton 5) 3% BG spores were added as a tracer to the spray suspension to enable viable assays to be done in parallel. Note also that before these latter trials, three small ground based trials were done outside the MRE building (near the "White Huts") in which BG spores were added as tracers. Dates are not cited.

9.3 The trials had shown that bacterial suspensions could be disseminated from fast flying aircraft at moderate rates of flow and useful degree of efficiency. However, none of the dissemination devices were deemed suitable for large area coverage. Whilst these can be regarded as essentially MRE trials, CDEE Field Trials Section was heavily involved, as was NGTE.

9.4 The Icing Tanker aircraft proving trials: 1966-1967

9.4.1 Attention then turned to an available aircraft with a suitable spraying system. A Canberra bomber at A&AEE Boscombe Down had been adapted as a tanker aircraft for use in icing up work on aircraft. It contained a 600 gallon holding tank and a second tank of 317 gallons. A spray rake at the rear was driven by compressed air. Because this aircraft was likely to be suitable for MRE's field trials with simulants, work was first undertaken to test the efficiency of the stirring mechanism in the storage tank, the amount of washing needed to clear the system of bacterial suspension and the contamination of the aircraft in flight during spraying. Trials were done from Boscombe Down in which EC traced with BG was disseminated from the aircraft. One trial was done on 21 June 1967, with dissemination of suspension in two spray runs at low altitude. The trial area is not identified in the first trial report but its location as Tarrant Rushton airfield in Dorset is identified in respect of the further trials. Tarrant Rushton airfield was then occupied by Flight Refuelling Ltd, who were contractors to A&AEE. In these proving trials concerned with spray nozzle efficiency, a 60 foot high sampling tower was erected on the airfield. Two further trials were done in June 1967 at Tarrant Rushton but these are recorded as unsuccessful, due to the excessive age of the suspension. The third and fourth trials were on 12 October 1967. In all four trials EC traced with BG was used. The detail of the trials are as follows:

Trial	Date	Duration of spraying (seconds)	Wind bearing	Range (ft)	Height of a/c above runway (ft)
1	21 June 1967	10	95-105°	1400	50
2	21 June 1967	315	120-125°	1500	N/A
3	12 October 1967	10	160°	900	60
4	12 October 1967	12½	160°	900	50

9.4.2 Note that trial No 2 involved no aircraft dissemination but the use of a May spray carried by a man held in the air by zero-lift balloons at sampling tower height, upwind of the tower.

9.5 Aerosol travel up to 15 miles from Porton: 1961-1962

The large area coverage trials by MRE: 1961-1968

9.5.1 The field trials described in 9.2 and 9.4 above were concerned with development of aircraft trials methodology, in relation to future large area concept trials. Whilst development continued, MRE conducted field trials wherein bacterial aerosols disseminated from the ground near MRE, were tracked for up to 15 miles downwind by teams of sampling personnel in vehicles on the Porton Range and sometimes in the countryside beyond. Suspensions of killed KA stained with primulin and traced with BG were disseminated from four 11-jet May sprays in the area of the White Huts. The details of the trials are as follows.

Trial No	Date	Sampling range	Wind direction
1	17 March 1961	3, 7½, 8¾, 14½ miles	?
2	3 August 1961	5 miles	NE
3	18 August 1961	5 miles	?
4	11 September 1961	50 yards + 5 miles	82°
5	14 September 1961	1¾, 9400 yards 17000 yards 15 miles	?
6	10 October 1961	10 miles	75°
7	20 October 1961	5 and 10 miles	80°
8	12 December 1961	5 miles	90°
9	11 January 1961	5 miles	38°
10	7 February 1961	9 miles	66°
11	9 May 1961	2, 5 and 9 miles	46°
12	22 June 1961	2 miles	-

9.5.2 Whilst sampling occurred on the Porton Range, the sampling ranges cited clearly show that during many trials the aerosol cloud extended beyond the limits of the Porton Range. Grid references are shown for a few sampling sites but the location of sampling points beyond the Porton Range is not always apparent. These were a fairly sophisticated series of field trials and provided the basis for those of 1963-1964 in the Lyme Bay area, when the bacterial aerosols were disseminated from a ship at sea. The Lyme Bay trials will be dealt with in the next section.

9.6 Testing sampling devices in the field: 1964

9.6.1 In 1964 two new sampling devices were tested on the Porton Range in short-range trials using a mixture of live EC traced with BG, disseminated from a double-headed May spray located outside the White Huts near MRE. Vehicles were stationed downwind to sample the air at distances of 300-400 yards and 900-2300 yards. The details are as follows:

Trial No	Date	Sampling range
1	26 June 1964	500 yards
2	26 June 1964	500 yards
3	3 July 1964	400 yards
4	7 July 1964	420 yards
5	7 July 1964	420 yards

6	7 July 1964	950 yards
7	9 July 1964	300 yards
8	9 July 1964	2100 yards
9	13 July 1964	380 yards
10	13 July 1964	950 yards

9.6.2 Wind directions were 230-360°. Whilst the distances, and time of dissemination, were short and activity was limited to the Porton Range, it is possible that some of the, by then, much diluted, aerosol cloud passed beyond the limits of the range. Live EC was used because this was critical to an evaluation of the sampling devices.

9.7 The Lyme Bay sea trials: 1963-1964

9.7.1 The basic objectives of this first group of Lyme Bay trials were to consolidate data on the Large Area Concept by the use of live bacterial simulants.

a. to determine the bacterial concentration downwind of a massive cross-wind line release;

b. to compare the viability of bacteria disseminated in the field at night with that of bacterial aerosols exposed in the laboratory to the same temperature and RH;

c. to determine whether the bacteria disseminated in the field retained their immunological properties i.e. did they still react with homologous anti-sera. (This last aspect was of critical importance to early warning and detection possibilities).

9.7.2 In April 1963 the 360 ton Experimental Trial Vessel (ETV) Icewhale was allocated to MRE for use as a spray vehicle. Lyme Bay and the surrounding countryside were selected because of the depth and semi-circular nature of the bay which enabled any wind direction between 070° through south to 280° to be used (provided that windspeed was suitable). A control site on Crown property for the trials was set up at Fleet, 3 miles west of Weymouth. The field trials team from MRE and CDEE traveled to Fleet on Mondays and returned on Fridays, leaving the control site protected by security guards. A Devon aircraft from A&AEE was used for meteorological work and air sampling. Sampling on the ground was by teams moving into the expected area of the aerosol cloud under radio control and locating at one of 20 predetermined convenient points e.g. several sites on Portland Bill and at Abbotsbury, Dorchester, Swyre, Weymouth sea front etc.

9.8 Most trials were done with suspensions of EC traced with BG spores. The batches of EC produced at MRE's pilot-plant were fully tested at MRE in accordance with the instructions of BRAB before dispatch to Fleet in metal barrels. The trials sequence was as below.

Trial serial	Date	Simulant	Source length	Downwind sampling distance inland
1	22 October 1963	Primulin-stained dead KA	4 miles	4-6 miles)) practice

2	23 October 1963	"	4.8 miles	5-10 miles) trials
3	14 November 1963	EC/BG	4 5 miles	10-14 miles
4	15 November 1963	"	4.6 miles	4-7 miles
5	4 December 1963	"	4.2 miles	4-7 miles
6	5 December 1963	"	4.3 miles	4-5 miles
7	7 January 1964	"	4.6 miles	3-6 miles
8	10 January 1964	"	4.6 miles	6-8 miles
9	27 January 1964	"	7.4 miles	9-14 miles
10	29 January 1964	"	9 miles	9-18 miles
11	27 February 1964	"	10.5 miles	7-14 miles
12	12 March 1964	"	6.25	5-17 miles
13	8 April 1964	"	16.65	13-23 miles
14	24 April 1964	"	17.6	18-20 miles

In each trial between 90 and 488 litres of suspension was disseminated from ETV Icewhale, according to the length of the line source. Note that Serials 1-4 were done in daylight and the rest at night.

9.9 Critical information which emerged from the complicated assessment was that:

a. EC aerosol viability decays more rapidly in the field than in the laboratory.

b. Viability of EC appears to be dependent upon the previous history of the air to which it is exposed.

These findings were of great importance to the Large Area Coverage concept but it was quite clear that viable bacteria could still exist at between 3 and 20 miles from a source at concentrations of 0.5-10 aerosol particles/litre of air. If viable pathogens were to be present at such concentrations, casualties would ensue.

9.10 The Lyme Bay sea trials: 1964-1965

9.10.1 Thirteen trials were conducted during this period. Generally, the line sources were longer, released further from the shore and the sampling was up to 37 nautical miles downwind. Also, the relevance to detection and early warning possibilities was increasing. The essentials were as in the Lyme Bay trials held in 1963-1964. The serial numbers used continued the sequence used in those trials. Details are as follows:

Trial serial	Date	Simulant	Source length	Downwind sampling distance inland
15	22 October 1964	EC/BG	7 4 miles	22.7 miles
16	6 November 1964	"	8.2 miles	8.8 miles
17	17 February 1965	"	13.5 miles	36.6 miles
18	19 February 1965	"	8.9 miles	16.9 miles
19	21 February 1965	"	7.1 miles	8.7 miles
20	9 March 1965	"	8 miles	14.4 miles
21	11 March 1965	"	9.2 miles	14.5 miles
22	13 March 1965	"	9.7 miles	18.3 miles

23	26 March 1965	"	9.4 miles	29.2 miles
24	9 April 1965	"	9 miles	22.9 miles
25	11 April 1965	"	14 miles	37.4 miles
26	30 April 1965	"	12.7 miles	28.2 miles
27	2 May 1965	"	14.2 miles	29.5 miles

9.10.2 Many more sampling sites were available in these trials (67 in all). Generally 5 mobile sampling vehicles were used. The dichotomy between results in field trials and in the Porton test sphere was again highlighted: EC survived better in the sphere than in the open air. Survival was also particle size dependent. The microthread technique was the only method applicable on a laboratory scale which has agreed with results in the field.

9.11 The Lyme Bay sea trials: 1966

9.11.1 The Lyme Bay trials continued during February and April 1966. During some of the earlier Lyme Bay trials simultaneous exposures of EC were made on microthreads. These showed that the microthread technique gave better agreement with viability determination in the field than in the laboratory or the Porton Test Sphere. The 1966 trials were to consolidate such data and to contribute to the problem of detection and early warning. This report is not particularly concerned with microthread aspects of the trials, since microthreads were "loaded" with simulants in the laboratory and exposed to the ambient air at the control site at Fleet, i.e. no dissemination of suspensions for such purposes occurred in the field. However, it is concerned with occasions when dissemination in the open air occurred i.e. in parallel work to compare field trials results with microthread results. The essentials were as reported for the 1964-1965 trials. The suspension of EC traced with BG was disseminated from ETV Icewhale in line sources of 8.8-11.4 nautical miles, released between 2 and 15 nautical miles off shore at night, using 4 heads of 11 May sprays. The details are as follows:

Trial serial	Date	Simulant	Source length	Downwind sampling inland
1	3 February 1966	EC/BG	10 n miles	9.7 miles
2	6 February 1966	"	10.6 n miles	21.7 miles
3	24 February 1966	"	11.4 n miles	20.6 miles
4	26 April 1966	"	8.75 n miles	17.2 miles

Note that microthread exposure at Fleet took place on four other dates as well as in those cited above.

9.11.2 It was found that the rates at which microthreads were ventilated in the open air had a small but consistent influence on viability. Like in the earlier Lyme Bay trials, MRE collaborated with CDEE.

9.12 The Lyme Bay sea trials: 1967-1968

By this period the deleterious Open Air Factor (OAF) had been identified as the prime factor in the viable decay of EC in the field. In these 1967-1968 Lyme Bay trials a

protective substance, termed S3, was added to the suspension of EC before dissemination to see if the effects of OAF could be nullified. The essentials of the trials were as previously described. Three trials were done under conditions with presumed OAF presence and two under conditions where little or no OAF was expected (OAF was believed to be in high concentration when air had previously passed over urban areas and absent or in low concentration, when the air had not). Microthread exposures were also made at one of the sampling sites. The details of the trials are as follows:

Trial serial	Date	Simulant	Source length (n miles)	Downwind sampling inland
1 (1)*	7 Nov 67	EC/BG	5.7	11.8
1 (2)	"	"	6.5	"
2 (1)	12 Nov 67	"	6.9	4.2
2 (2)	"	"	7	"
3 (1)	1 Dec 67	"	5.2	7
3 (2)	"	"	6 1	"
4 (1)	20 Jan 68	"	7	6.3
4 (2)	"	"	6.9	"
5 (1)	22 Jan 68	"	6 6	7
5 (2)	"	"	6.6	7

* *Two spray runs were made by ETV Icewhale i.e. along a reciprocal course, the second run with S3 added to the suspension*

10. The microthread field trials: 1964-1973

10.1 The gradual emergence of the microthread technique led to some diminution of the large field trials involving aerosol dissemination of EC and other simulants. The Large Area Coverage concept had been validated and attention now turned to a detailed study of OAF and other factors affecting aerosol viability: this was largely pursued with the microthread technique. Large-scale dissemination was still used but tended to be for studies on the vulnerability of ships at sea, biological shelters and in the context of detection and early warning. Since the microthread trials usually involved no dissemination of aerosols in the field but the mere holding of charged microthread frames in the ambient air at different locations, they should be of little concern to the media and the public on grounds of either safety or ethics.

10.2 The microthread field trials have attracted concern because many microthread-holding locations have been in cities e.g. Southampton. The citation of such locations by the media, void of any clear understanding of events during trials, have latterly caused much apprehension amongst those who inferred that bacteria had been disseminated as aerosols within cities.

10.3 Dorset microthread trials: 1964-1965

By 1964 there was a need to use simultaneous experiments with EC in the microthread technique, in field trials and in the test sphere. EC/BG was charged onto microthreads at the AUWE site on Portland Bill by exposing them in aspirated sows to the aerosol disseminated from a hand-held, double-nozzle May spray operating 40 yards upwind i.e. there was al fresco release of the simulant mixture. It seems certain that the microthreads were charged on the same day as they were exposed to the ambient air at three sites in Dorset, i.e. Osmington Mills, Maiden Castle and the AUWE site on Portland Bill. If this is so then the disseminations occurred on:

6 November 1964
17 February 1965
19 February 1965
21 February 1965
9 March 1965
11 March 1965
13 March 1965
26 March 1965
9 April 1965
11 April 1965
30 April 1965
2 May 1965.

10.4 In the proper field trial element of the work, EC/BG was disseminated from four spray heads, each of 11 May sprays carried on ETV Icewhale, steaming 5-20 miles off shore in Lyme Bay or Weymouth Bay. Mobile sampling stations were deployed inland downwind of the source. These disseminations at sea occurred on the same dates as the microthreads were charged and used i.e. as given above.

10.5 This major study confirmed the invalidity of the Test Sphere for predicting the survival of microorganisms in the outside air and confirmed that the microthread technique is the only laboratory method which agreed with results obtained in the field.

10.6 Microthread trials in and around Southampton: 1965

Trials in 1965 involved exposing microthreads charged with EC/BG to the ambient air at night, upwind and downwind of Southampton. The microthreads were charged in a modified Henderson apparatus mounted in a truck i.e. no al fresco dissemination was involved. Sealed sows containing microthreads were subsequently transported to exposure sites; the microthreads now exposed in roundabouts were subsequently eluted at intervals up to 2 hours for assay . Six trials each with six exposure sites upwind of the city and six downwind were done. A base for the trials, with the mobile laboratories, was set up at the No 17 Port Regiment RCT, McMullen Barracks at Marchwood.

10.7 Microthread work at St Bartholomew's Hospital Medical College in London: 1968

In an attempt to identify the nature of OAF, EC/BG charged onto microthreads was exposed to a variety of pollutants in a 20 m^3 chamber on the fourth floor of the College. The venue for the charging is not stated but it was done within a modified Henderson apparatus and the charged microthreads were transferred into roundabouts inside the chamber. No dates are given in the 1968 report. The chamber was made available by Dr P J Lawther, a member of BRAB.

10.8 Microthread work on MRE roof and in London: 1965

EC/BG charged onto microthreads in a modified Henderson apparatus was exposed to ambient air on the roof of MRE, at Maiden Castle and a Portland Bill site. At the latter two sites, it is possible that the work is reported above, since 19 February 1965 and 9 April 1965 are cited. A new venue cited here is Waterloo Bridge in London where charged microthreads were carried from Waterloo Bridge along the northern embankment to Westminster Bridge and back to Waterloo on the southern embankment, during the rush hour. Microthreads were eluted for assay en route. No dates are cited; pre-August 1965 is indicated from the date of the report.

10.9 Microthread work near Southampton and Swindon: 1966

10.9.1 In 1966, microthread work was repeated and extended to the summer months when air pollution from industry was at its lowest, in the Southampton and Swindon areas. EC/BG was charged onto microthreads in a truck-mounted modified Henderson apparatus and transported to exposure sites. Nineteen trials were done near Southampton and four around Swindon. The dates are as follows:

a. **Southampton:**
- 18 July 1966
- 19 July 1966
- 20 July 1966

22 August 1966
23 August 1966
24 August 1966
- 25 August 1966
- 7 November 1966
- 8 November 1966
- 9 November 1966
- 10 November 1966
21 November 1966
- 22 November 1966
- 23 November 1966
- 24 November 1966
- 12 December 1966
- 13 December 1966
- 14 December 1966
- 15 December 1966

b. **Swindon:**
- 5 September 1966
- 6 September 1966
- 7 September 1966
- 8 September 1966.

10.9.2 The exposure sites used are briefly described and their grid reference given in the report. The bases for these trials were at No 17 Port Regiment RCT, McMullen Barracks, Marchwood and No 15 MU RAF Wroughton.

10.10 Microthread work on SEB: 1973

To assess the aerosol stability of the toxin SEB charged microthreads were exposed to the open air in a special ventilated safety cabinet on the roof of MRE. The microthreads had been charged under stringent safety conditions. The dates of the work were 10, 11, 12 April, 9, 18, 25 30 October and 8, 15, 18 November 1973. Whilst no al fresco dissemination or uncontained microthread exposure to the ambient air occurred, the field trial is nevertheless worthy of reporting here.

10.11 Microthread work on protection against OAF: 1964-1967

Some work with microthreads charged with live EC traced with BG and live SM was done on the roof of MRE after 1964 and before July 1967. The earlier charging of the microthreads with the bacterial suspensions containing some protective compound also appears to have been done on the roof of MRE from a Collison spray and a May spray i.e. al fresco dissemination. No dates or full details are given.

11. More trials at sea: 1970

11.1 Trial Kolanut: 1970

There was reasonable agreement between the viable decay rates of microorganisms on microthreads and those disseminated into a ship's ventilating system. The purpose of Trial Kolanut was to expose HMS ANDROMEDA to an aerosol cloud at sea in the English Channel off Portland Bill and determine the penetration of the ship by the aerosol under different states e.g. citadel and non-citadel conditions. The simulant was EC traced with BG, disseminated from ETV Icewhale upwind of the frigate on three successive nights (7, 8 and 9 December 1970). HMS ANDROMEDA passed through the cloud disseminated as a line source 90° to the wind direction, 10 minutes after the dissemination and three nautical miles downwind. Samplers of diverse types were deployed within the ship. Results showed that unprotected personnel in all parts of the ship would have been at risk if an actual BW agent was to be used in a similar way. Whilst large numbers of the ship's crew were exposed to aerosols of the simulant, the location of the dissemination, the short source lines used and the wind direction suggest that little of the aerosol cloud passed over land. Note that some control microthread tests were also carried out in this trial.

11.2 Navy trial VARAN: 1973

11.2.1 MRE, at the request of DNW, evaluated the validity of the stated naval position that the citadel condition can provide protection from BW attack to the ship's company. Also, the penetration of a ship in the normal i.e. non-citadel condition by a microbial aerosol release 15-30 km upwind was measured. This second objective was to extend the information from Trial Kolanut. The trial involved the frigate HMS ACHILLES at sea in the Portland Bill area. Dissemination of BG suspension was from a Land Rover equipped with a 22 nozzle May spray and carried on the foredeck of ETV Whimbrel. Details are:

Date	Serial	Wind direction
8 January 1973	7	55°
8 January 1973	8	55°
8 January 1973	6	55°
9 January 1973	5	40°
9 January 1973	4	70°
9 January 1973	3	variable
10 January 1973	1A	(not cited)
10 January 1973	1	(failure)
11 January 1973	2	120-150°

11.2.2 Generally, ETV Whimbrel and HMS ACHILLES steamed on parallel courses separated by 200-2000 metres: dissemination lasted for 21-27 minutes. Whilst the trial report gives windspeed and direction, length of the line source and times, no information is given on the precise sea location of the ETV Whimbrel during dissemination. Estimation of the extent of any downwind drift of the disseminated aerosol over the coast is not possible. It is clear that in the non-citadel state, the ship's company was exposed to BG spores.

12. Detection trials: 1971-1978

12.1 Collaborative UK/US trials: 1971

12.1.1 Whilst some aspects of detection and early warning of aerosolised microorganisms had been evaluated in field trials, no large trials had been conducted to evaluate, under realistic conditions, the potentials of techniques developed largely on the basis of laboratory work. During the preparation of the UK's Naval, General, Air Staff Target (NGAST) 3083 feasibility study for a detection system, a series of conjoint UK/US field trials were held at Portland Bill within the perimeter of the then AUWE and on the Porton Range. Both parts involved the dissemination of killed SM traced with BG. Neither the UK nor US detectors under trial depended on bacterial viability to detect the simulant SM, thus it was considered expedient to inactivate the SM. (Referred to as ISM below). Dissemination at Portland was from ETV Icewhale through four multiple spray heads of 11 jets each. At Porton, the spray used was similar but mounted on a lorry. The vessel was controlled from the site at Fleet used in earlier trials. In view of the large number of dissemination serials at Portland (16) and Porton (34) the full details cannot be summarised here. The ETV Icewhale laid down line sources on a variety of courses to permit the wind to carry the aerosol cloud over the AUWE area on Portland Bill. At Porton, the mobile spray operated along a perimeter road upwind of the sampling site in the bowl of the Range. Here the distances between source and samplers were much closer than at Portland. On some nine occasions, a "blank" spray of 0.5% phenol (reflecting the inactivating agent present in the SM/BG suspension) was disseminated to provide a control. Also, at Porton BG alone was disseminated on 3 occasions.

12.1.2 The dates and basic details are

Serial	Date	Simulant or blank
Portland		
1	15 November 1971	ISM/BG
2	"	ISM/BG
3	"	Phenol
4	"	ISM/BG
5	"	Phenol
6	16 November 1971	ISM/BG
7	"	Phenol
[redacted]	17 November 1971	ISM/BG
9	"	Phenol
10	"	ISM/BG
11	"	ISM/BG
12	20 November 1971	ISM/BG
13	24 November 1971	ISM/BG
14	"	ISM/BG
15	25 November 1971	ISM/BG
16	"	ISM/BG
Porton Range		
17	1 December 1971	ISM/BG
18	"	ISM/BG
19	"	Phenol
20	"	ISM/BG

Serial	Date	Simulant or blank
21	"	ISM/BG
22	"	Phenol
23	3 December 1971	ISM/BG
24	"	Phenol
25	"	ISM/BG
26	"	ISM/BG
27	"	ISM/BG
28	"	ISM/BG
29	"	ISM/BG
30	6 December 1971	ISM/BG
31	"	ISM/BG
32	"	Phenol
33	"	ISM/BG
34	"	ISM/BG
35	"	ISM/BG
36	"	ISM/BG
37	7 December 1971	ISM/BG
38	"	Phenol
39	"	ISM/BG
40	"	ISM/BG
41	"	ISM/BG
42	"	ISM/BG
43	"	ISM/BG
44	9 December 1997	ISM/BG
45	"	BG
46	"	ISM/BG
47	"	BG
48	"	ISM/BG
49	"	ISM/BG
50	"	BG

12.1.3 Between 1 May 1974 and 19 June 1974 a MRE-constructed copy of the US Chemiluminescence Detector Model II (Chemi II) was evaluated on the Porton Range. The simulants used to challenge the detection apparatus were:

a. killed EC at five different concentrations traced with live BG;

b. killed SM (strain UK8) traced with live BG;

c. killed SM alone;

d. BG alone.

These were disseminated in separate serials from a 1, 11 or 22 nozzle May spray carried in a Land Rover driven along a section of the perimeter road. Seven challenges were done on each trial day. Challenges 1-20 were concerned with establishing trials procedure and occurred between 5 February-13 February 1974. Serials 21-83 were concerned with graded challenges to meet the objectives of the trial and were between 1 May 1974 and

24 May 1974. Distances from the spray to the detectors carried on static Land Rovers were circa 600-1650 metres. Spraying occurred over 8-22 minutes.

12.1.4 In the evaluation of an important bacterial identification technique based on I^{125}-labeled antibody against EC, BG and SM, data on related field trials in the bowl of the Porton Range are described. These trials were on:

25 May 1974
30 May 1974
17 June 1974
19 June 1974
24 June 1974.

Both SM and EC were inactivated with phenol. Challenge aerosols of mixtures of BG with killed EC or with killed SM were disseminated upwind of the air sampling vehicles from a spray-carrying vehicle on a perimeter road.

12.2 Studies on Microbiological Aerosol Pattern Recognition Equipment (MAPRE): 1978

During the development of MAPRE, samples of background air were collected at several sites on the Porton Range, Chelsea, Sutton Coldfield, Aberporth and Shoeburyness. Also, six small field trials using inactivated EC or SM traced with BG, and with BG alone, involving dissemination 80 or 1 kilometer metres upwind of the MAPRE assembly were done. The means of dissemination are not given: most of the described work is connected with the Test Sphere. No dates, venues or details are provided: the work must have been concluded by October 1978 and probably took place in that year on the Porton Range.

12.3 DICE trials: collaboration UK/US trials: 1975

Field trials of a collaborative UK/US nature were held in 1975 under the euphemistic title DICE. Phase I involved no challenge of developed detectors with microbial aerosols in the field but the protracted sampling of background air between July and August 1975. This was done at the following sites:

P&EE Shoeburyness	7-15 July
Chelsea Barracks, London	16-24 July
St George's Barracks, Sutton Coldfield	25 July-4 August
CDE Nancekuke	5-12 August
CDE Porton	13-24 August.

A further phase of DICE was held at sea, again to sample naturally occurring aerosols. A later phase, to study naturally occurring aerosols in the then Western Germany, involved sampling at:

Grafenwoher, near Nuremberg

Wildeflechen, near Frankfurt

Baumholder, near Saarbruken.

No al fresco disseminations occurred in Phases I and II but these trials are worthy of note because of the diverse locations for the UK/US team.

12.4 The third phase of DICE involved the al fresco dissemination of phenol-killed SM traced with BG from two multiple spray heads, each of 11 jets carried on a Land Rover mounted on the deck of Fleet Tender Cockchafer, in Lyme and Weymouth Bays. Between 29 September and 21 October 1975, 24 disseminations were done to challenge biological aerosol detectors.

13. Smaller Field Trials: 1968-1977

13.1 Some assessments of sampling equipment made during the period of the Lyme Bay trials may have been based partly on one or more of the serials of those trials and also on other trials on the Porton Range, often involving several dissemination devices. Such apparently separate small field trials may present red herrings to the unperceptive. For this reason, the trials are worth a separate section in this report.

13.2 A further series of field trials reported in 1975 to evaluate the Aerojet General Liquid Scrubber All-Glass Cyclone refers to the open air dissemination of EC/BG. Here dissemination by a May spray i.e. a single source, operated for 3 minutes along a 75-100 metres line at right angles to the wind and 75-250 metres upwind of a sampling site, is cited. A multiple head May spray was also similarly operated at longer range. Additionally, a sampling site was in operation on the roof of MRE. This suggests that these trials were conducted on the Porton Range. No dates are given in the report. Some seven trials serials are cited. In 1974 similar trials were done with BG alone: no details are provided about the 1974 trials. Some seven serials appear to have been done with EC/BG. Identification of the venue for field trials is only possible because the MRE building roof is cited as a sampling point for some serials in the report. No dates are given.

13.3 A further set of field trials reported in 1976 concerned with decontamination refers, to a man-portable single jet May spray being used to disseminate BG at circa "10 ml per metre of track"; a short 50 metre line source was involved. No dates are cited and no trials site is identified. It seems reasonable to conclude that the Porton Range was used but there is no conclusive proof.

13.4 In another small series of trials in 1968 MRE investigated the escape of microorganisms from the vacuum pump outlet of a bulk collection milk tanker. This work was to assess whether such methods of milk collection could have contributed to the recent outbreak of foot and mouth disease in the UK. Whether MRE was tasked to do this work is not clear but the Milk Marketing Board collaborated. Four hundred gallons of milk were contaminated with BG. Milk was transferred from a bowser to the tanker. Air sampling devices were located downwind of the ensemble. The four trials showed that aerosols of milk containing BG escaped into the air. The extent of the disseminations was determined. A mean of 479 spores escaped into the air each minute when the milk pump was in operation. Whilst this trial did not involve the use of a device constructed for aerosolisation per se, it clearly involved some release of BG into the air and is therefore included in this report. No dates were reported. No trials site was identified but it seems reasonable to conclude that this was the Porton Range.

13.5 In 1972 the vulnerability of the NBC collective protection systems in the SPARTAN and the SCIMITAR armoured personnel carriers (APC) were tested by MRE in field trials on the Porton Range. BG was disseminated at a rate of 3 litres/minute from three multi-jet May spray heads mounted on a lorry, emitting from a 400-700 metres line source in 15 minutes. Samplers were mounted within the APCs and elsewhere on the layout. The details are:

Serial	Date	Range from source to layout (metres)
SPARTAN		
1	10 January 1972	1000-1200
2	12 January 1972	1000-1200
3	21 January 1972	900-1000
4	24 January 1972	1500-1600
5	26 January 1972	1300-1600
6	28 January 1972	900
7	3 February 1972	850-1050
SCIMITAR		
1	14 February 1972	900
2	16 February 1972	1400
3	21 February 1972	850-950
4	23 February 1972	900-1050
5	25 February 1972	850-1050
6	28 February 1972	700-1000

13.6 At the request of DNW, MRE carried out field trials on the Porton Range in 1972 and 1973 to study the deposition of microbial aerosols on clothing and hair and to assess subsequent reaerosolisation during removal of contaminated clothing. Most work was done on the Porton Range although the trial report includes work carried out at sea during Navy Trial VARAN. Much laboratory work in the White Huts, near MRE was also involved. In the field, men, man-sized clothed dummies and frames carrying diverse sorts of clothing fabrics were exposed to BG aerosols disseminated from a May-type 22 nozzle spray carried on a Land Rover moving at about 1 metre/second 600-1000 metres upwind of the test subjects or to a single spray nozzle carried by a man at slow walking speed some 100 metres upwind. In each test in the field 3-6 men were exposed: the report gives no clue as to their origin or to their absolute number. There is no evidence that they were Service volunteers and it is likely that they were members of MRE staff. After exposure, for some serials, the men undressed in a dedicated enclosed chamber from which the air was sampled to detect reaerosolisation during undressing. A similar smaller chamber was used to study reaerosolisation from hair. No dates are given.

13.7 Since the Home Office had asked MRE to investigate simple collective protection for the civil population i.e. Simple Biological Shelters, MRE acquired two Portakabin buildings for test purposes, particularly in the study of airlocks for pressurised structures. In field trials on the Porton Range during 1974 to study the penetration of aerosolised microorganisms into closed Portakabins, BG was disseminated from a multi-jet May spray carried on a Land Rover traveling on a track at right angles to the wind direction some 800-1400 metres upwind of the Portakabins. No precise location on the Porton Range is described in the trials report although it appears to be within the bowl of the Range. The aerosol cloud was sampled inside and outside the Portakabins. Wind directions were between 073° and 245°. Dissemination was done between 6 March and 25 March 1974 but no precise dates are cited. Results showed that the total dosage of aerosol inside the Portakabin rooms reached up to 77% of the concentration outside.

Smaller Field Trials: 1968-1977

13.8 In 1975, MRE conducted trials to measure the penetration of aerosol particles into the NBC collective protection system fitted to FV438, a Swingfire missile launcher APC. This involved the dissemination, for periods of 25 minutes, of BG from the May spray carried on a Land Rover and situated between 800 and 1300 metres upwind of the test area on the Porton Range. Seven disseminations were done under various test conditions e.g. the FV438 moving or stationary, the former around a 50 metre square on the Range.

13.9 1975 saw the second part of MRE field trials on Simple Biological Shelters. These were concerned with systems which could be installed in rooms within a building. Test rooms were prepared, with sheet polythene liners and positive ventilation units, within the existing Portakabins. Procedures were much as in the first part of the trials in 1974. Spraying periods were 17½-28 minutes. Wind direction was circa 200°-345°. No specific dates are cited.

13.10 In 1975, MRE conducted Navy Trial GONDOLIER in the NBC Protection Training Unit (PTU) at PHOENIX NBCD School, Portsmouth. Essentially, the study was concerned with decontamination and cleansing of ship's personnel after a BW attack. Men, presumably naval personnel, dressed in several types of clothing, respirators, NBC gloves and NBC boots were exposed to BG disseminated in the open air within the PHOENIX NBCD School. Dissemination was from a man-portable single-nozzle May spray about 80 metres upwind of the subjects. The men then entered the PTU and engaged in undressing and changing drills within the cleansing station. Air sampling and swab samples were taken to determine deposition on clothing, on surfaces in the various rooms under the PTU. Six disseminations were made on 5, 7, 9, 12, 14 and 15 May.

13.11 In 1974 DNW tasked MRE to investigate the effectiveness of the ship installed pre-wetting system for removing biological agent aerosols deposited on ships' structures. This was done on the Porton Range and at the AUWE compound at Portland Bill using metre square steel plates, painted to current RN standards, as test surfaces. A suspension of BG was disseminated from a man-portable single jet May spray, traversing a path at right angles to the wind and about 40 metres upwind of the test plates. A mock-up pre-wetting spray system was used. Residues on the plates were assayed. Some eight serials were done on Porton Ranges and two at AUWE. No dates are given.

13.12 In 1976, MRE described field trials on comparative decontaminant evaluation. These involved dissemination of BG from a man-portable one-jet May spray carried along a 50 metre line, 75-100 metres upwind of test equipment, protective clothing and steel plates. Whilst the venue appears to be the Porton Range, this is not stated. Air sampling from Land Rovers situated alongside the test site is cited. No dates are cited.

13.13 In 1977, MRE conducted a series of trials to determine the possibilities of retrospective identification of BW agents after an attack by sampling from the hair, respiratory tract and clothing of exposed individuals. The trials were done with SM traced with BG, EC traced with BG and BG alone. BG was disseminated in the open air, using a man-portable spray 80-200 metres upwind of the site on the Porton Range, and SM and EC in a Portakabin using a Humbrol paint spray gun. Men and vehicles were exposed in the open

air: respirators were not worn. Men, wearing respirators, and furnishings were also exposed within rooms of a Portakabin. The identity of the personnel is not shown in the report but they appear to have been 24 in number. There is no evidence that these were Service volunteers. Only four men, wearing respirators, appear to have been exposed to SM and EC inside the Portakabin. There was obviously a relatively rapid viable decay of SM and EC within the Portakabins. Very small quantities, i.e. 1 ml of suspension, of SM and EC were disseminated within the rooms of the Portakabin. The Portakabin was decontaminated after the trial. No dates are given.

13.14 In 1976, MRE evaluated the utility of unsophisticated spraying devices. Three devices, bought from local shops, were tested in field trials on the Porton Range with the reference May spray, using BG. Some 16 serials used the May spray and 14 serials were apportioned to the other sprays. All were hand-held and the doses in the aerosol clouds determined from air samples taken at 80-200 metres downwind. The mean output per metre of track for each spray was 1-3.4 x 10^{11} but there is little information on the absolute concentration of BG disseminated. Dates are not given.

13.15 A CDE Report dealing with the operation of 15th Field Ambulance, Tidworth in a toxic environment and authored by conjoint CDE and MRE staff, shows that in June and July 1972 in the bowl of the Range, BG was disseminated on five occasions upwind of the tented field ambulance site. Servicemen of the unit, clad in two Marks of the NBC suit were involved. "Uvitex" was used as the CW agent simulant. The BG was disseminated from a moving source vehicle at a range of 680-1600 metres from the tents. No further details of the simulant dissemination are given. The BG concentrations recovered in the open and inside the system are given.

13.16 Sometime between 1951 and October 1954, in the context of improved sampling devices evaluation in the laboratory and field, a mixture of live SM and BG was disseminated "outside" MRD in autumn weather. This suggests the area of the White Huts. Dissemination occurred from a "Harness" spray as used in Operation OZONE on eight occasions. Sampling devices were arranged at 30-50 yards from the source. No other data are given.

13.17 In the study of collection devices small-scale field trials are cited wherein live SM traced with BG was disseminated. No dates as given but these must be before September 1956.

13.18 In a similar study reported in 1958, more small-scale field trials are cited where aerosols were disseminated by single or multiple-jet May sprays. These trials involve some with BG spores but few details are given beyond hand-held sprays and a 50 yard distance from source to sampler. The dates are given as 19 February, 4 March and 14 March 1958.

13.19 In an evaluation of the Anderson sampler in 1962, a field trial is cited involving the dissemination of killed and primuline-stained K. aerogenes, traced and not traced with BG, five miles upwind of a sampling station. The date is cited as 9 May 1962. No location is cited but this is likely to have been the Porton Range, with the source possibly in the area of the White Huts. No further significant detail is given.

14. N Cattle-cake feeding trials: 1941 and X-grenade trials: 1944

14.1 These trials are mentioned here as part of the historical record of BW-related trials of W.W.II even though, unlike the other field trials dealt with, they involved no dissemination of microbial aerosols into the open air and no microthread methods were involved.

14.2 The N cattle-cake feeding trials

The W.W.II stockpiling by the UK of 5,000,000 cattle-cakes containing a lethal dose of anthrax spores intended to be a UK interim retaliatory BW capability, is fairly well known, having been given some publicity by Paxman and Harris in their 1982 book "A higher form of killing. This ad hoc anti-livestock weapon was destroyed at the end of W.W.II. In the early development stages of the cattle-cake project several species of large animals i.e. cattle, sheep and horses were fed with contaminated cattle-cake on a site on the Porton Range. The animals killed by anthrax were buried where they fell, on the site.

14.3 The X-grenade trials: 1944

During W.W.II, BDP pursued occasional research on behalf of the Special Operations Executive (SOE). One such topic was the feasibility of ensuring the lethality of otherwise non-lethal injuries from munitions such as grenades, by the incorporation of some toxic material e.g. coating metal fragments within grenades with X, the W.W.II code for botulinum toxin. In April 1944 a trial was held in a pill box on the Porton Range. Several goats were exposed to the explosion of an ad hoc grenade containing a mass of contaminated grub screws. Results indicated that the lethality of minor trauma could be assured by the use of X. No further work was done on this topic. No persistent contamination resulted.

15. Discussion

15.1 This report was commissioned as a source of information on BW and BW defence field trials conducted by the UK from 1940-1979. These years mark the inception of practical work at Porton by BDP and the closure of the successor Establishment MRE in 1979. The current interest in such field trials has been largely stimulated by the increase in Parliamentary Questions and enquiries from about the mid-1980s and which have their roots in MRD/MRE reports made available to BRAB and ultimately placed in the PRO.

15.2 What are the lessons which emerge for the future from this account of 1940-1979 field trials? No mandate to suggest essential needs was associated with the tasking for this report but the complexity of retrospective investigation over nearly 40 years of field trials are such that it seems essential to list some future requirements.

15.2.1 There must be a central and definitive register of all trials programmes and trials reports.

15.2.2 The documentation must provide adequate detail of the sort which may be sought in the context of Parliamentary Questions and other enquiries.

15.2.3 Each trial should have a definitive and unique serial number. No field trial however small or mundane should be excepted.

15.2.4 The documentation should show:

a. Sites of dissemination and sampling with grid references for these.

b. Date, time, identity of simulant, concentration of simulant in the suspension as disseminated, the volume disseminated, wind direction, wind speed and other meteorological data to enable an assessment of the extent of the aerosol cloud and particularly its movement downwind beyond the trials site.

c. Details of any safety testing of the batch of simulant used and details of the origin and provenance of the batch.

d The names and departmental location of all personnel involved in the trial and the nature of their duties.

e. Correlation of field trials programmes with field trials reports. Some report documentation should emerge, even for aborted for failed trials.

f The documentation should be stored in perpetuity at some central point in CBD and should be readily retrievable, as should be relevant data originating in diverse departments.

15.3 These requirements may seem obvious and credulous but it is inescapable that they were not always extant in the past. Most trials conducted by BDP, MRD and MRE are now only accessible through a formal report which presents the essentials of the procedures and the results. Few such reports contain the amount of detail now needed to fulfil modern enquiries which arise from Parliamentary and public concerns.

16. Conclusions

16.1 A fairly detailed chronology of BW and BW defence field trials covering the period 1940-1979 has been assembled from the archive.

16.2 This study reveals that often insufficient data has been preserved to fulfil present day needs to respond to Parliamentary and public enquiries.

16.3 Some ways of obviating such deficiencies in the recording of contemporary field trials are suggested.

16.4 There is little that can be done to remedy deficiencies in the past reporting of BW and BW defence field trials and more intensive interrogation of the MRE archive is not likely to result in the acquisition of further knowledge or discover hitherto unreported trials.

16.5 What is summarised here probably represents more than a 95% complete account of the field trials with simulants and certainly a 100% complete account of field trials which involved the dissemination of pathogens in the open air.

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Report documentation page

1. Originator's report number:	DERA/CBD/CR990038
2. Originator's Name and Location:	[redacted]
3. MOD Contract number and period covered:	38LAXXX1
4. MOD Sponsor's Name and Location:	ADR(CBD) MOD Main Building, Whitehall, London
5. Report Classification and Caveats in use: UNCLASSIFIED	6. Date written: Pagination: References:
7a. Report Title:	BW and BW Defence Field Trials Conducted by the UK: 1940-1979
7b. Translation / Conference details (if translation give foreign title / if part of conference then give conference particulars):	
7c. Title classification:	UNCLASSIFIED
8. Authors:	[redacted]
9. Descriptors / Key words:	Field trials, BW, BW defence, history, BDP, MRD, MRE, N, W, L, X, UL, US, FP, SM, BG, U, EC, MRE162, SEB, sabotage, detection, simulants, HARNESS, CAULDRON, HESPERUS, OZONE, NEGATION, Gruinard, Penclawdd, Underground, Westwood, GPO, Icing Tanker, Lyme Bay, Dorset, Southampton, Swindon, OAF, KOLANUT, VARAN, DICE, MAPRE, Archive.

10a. Abstract. (An abstract should aim to give an informative and concise summary of the report in up to 300 words).

This report surveys, the BW and BW defence trials conducted by the Porton Establishment and notably MRE and its precursors from 1940-1979. The survey is probably more than 95% complete. It is a largely chronological history and arises from perusal of a large volume of reports and files. Deficiencies existed in many past records of field trials in the context of modern enquiries from Parliament and the public. Such deficiencies are now hardly remediable but they could be avoided in the future. A brief rationale for the future recording of CBD Sector field trials is outlined.

10b. Abstract classification: UNCLASSIFIED	FORM MEETS DRIC 1000 ISSUE 5

Report documentation page

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