SECRET

SECRET
GUARD

82/56

O.S.2

FROM WHOM	DATE
DIRECTOR TACTICAL, SHIP REQUIREMENTS & STAFF DUTIES DIVISION	13th March, 1956.

MARKINGS TO BOARD TO	TRANSIT LIST SENT BY	SUBJECT
PRO		Operation MOSAIC - Stationing of DIANA for Scientific Observation of Fall-Out (signal enclosed.)

FORMER(S)

ADM 1/26714

Movement of a paper is invariably to be notified by Transit List to the parent department except when the paper itself is being returned straight there. Despatch of the Transit List is to be certified by initialling the appropriate column.

DATE IN	REFERRED TO	TRANSIT LIST SENT BY	DATE IN	REFERRED TO	TRANSIT LIST SENT BY
	~~M.D.G.~~				
	D.C.(R.&D.)				
1956	~~D.P.R.~~				
	~~D.O.D.~~				
	~~D.S.D.~~				
	D.T.S.D.				

RE-REVIEW.
1993

PA.T.R. (25 years)
25/1/60

18/10/83 S

C.P. Marchant
27-4-94 'O'

SECRET GUARD

On 8th February, 1956 D.T.S.D. held a meeting to discuss details of the trial requirements for H.M.S. DIANA in Operation MOSAIC. Minutes of this meeting were circulated under T.S.D. 4046/56 dated 15th February, 1956 - copy enclosed.

2. At this meeting it was agreed that, in order to assist in the stationing of DIANA (and an unmanned whaler) so that fall-out would be received onboard without undue hazard to personnel, an appreciation would be prepared jointly by D.P.R. and A.W.R.E. for onward transmission to Commodore, Special Squadron and the Commanding Officer, H.M.S. DIANA.

3. Enclosed herein is DPR/BWS/79/56 dated 9th March, 1956 covering a paper so prepared.

4. In agreement with D.P.R., D.T.S.D. has, in pencil, made three alterations to this paper, viz:-

(a) In para.3.2, the "rep" values and note have been deleted since DIANA will not be able to determine such values, and the levels of external radiation (given in rontgens) are adequate on their own.

(b) Para.9.2. has been amended so that the onus of positioning the unmanned whaler should rest on the Commanding Officer, H.M.S. DIANA, as advised by technical experts, since this would seem to be more in accordance with service custom.

(c) A note has been added after the table of distances in para.6.8.

5. Subject to M.D.G.'s concurrence as regards radiation effects on personnel, it is now proposed that copies of the paper enclosed, as amended, should be sent to all concerned in DIANA's observations, under a covering letter in the following sense:-

Addressed - The Commodore, Special Squadron.

Copies to - The Commanding Officer, H.M.S. DIANA
The Superintendent, A.R.L.
The Director, A.W.R.E. (5 copies)
The Captain, H.M.S. PHOENIX
The C. in C. Far East Station.

Internal Distribution to - V.C.N.S., Controller, D.C.N.S. D.C. (R. & D.), A.C.N.S.(W), A.C.N.S., N.A.1 S.L., D.N.E., D.O.D., D.N.C., D.P.R., E. in C., D.O.R., M.D.G., D.T.S.D.

/Refer....

SECRET GUARD

Refer to A.M.151246Z/December (copy attached) and say that consideration has been given to the stationing of H.M.S. DIANA and the unmanned whaler during Operation MOSAIC.

The attached paper, which includes agreed joint recommendations by Admiralty and A.W.R.E., is an appreciation of the factors involved and is forwarded for guidance.

Notwithstanding, it is accepted that the safety of H.M.S. DIANA and her ship's company during Operation MOSAIC is a Naval responsibility and, as such, will be outside the immediate concern of the A.W.R.E. Health authorities at the time of the operation.

6. M.D.G. referred and then to Head of M. Branch to submit, through D.C. (R. & D.) to D.C.N.S. for approval as para.5 above. Copy of this minute to D.P.R. Docket has been made YELLOW as it is desired that DIANA should receive this paper before leaving U.K.

for DIRECTOR TACTICAL, SHIP REQUIREMENTS & STAFF DUTIES DIVISION
13th March, 1956.

M.D.G. concurs in the estimates of radiation effects on personnel quoted by D.P.R.

2. Even if the whole ship's company were exposed to the 'special higher integrated dose' of 25 r it is unlikely that any casualties would occur.

3. M.D.G. agrees with the amendments proposed by D.T.S.D.

J. M. Holford
for M.D.G.
15. 3. 56

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(40506) Wt 47791—P6418 50000 10/54 W.O.P.

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Register No. T.S.D. 82/56

Minute Sheet No. 2

As a result of a meeting held by D.T.S.D. on 8th February, 1956, to discuss details of the trial requirements for H.M.S. DIANA in Operation MOSAIC, A.R.L., in conjunction with A.W.R.E., produced the enclosed estimate of the extent of fall-out likely to be experienced in the operation.

2. This report is intended to guide the Commodore, Special Squadron in his choice of station for DIANA which will obtain the best results commensurate with the safety of the crew.

3. D.T.S.D. has proposed certain amendments, all of which appear to be desirable. M.D.G. in agreeing generally with the report, remarks on paragraph 3 in particular, stating that even if the whole crew received the maximum radiation exposure permitted in the operation the likelihood of casualties is remote.

4. A.W.R.E. is anxious that the Commodore, Special Squadron should be in no doubt that, while the report provides the most up-to-date assessment of what is expected, the responsibility for the safety of DIANA and her company remains with the Royal Navy.

5. It is proposed to distribute the report to the authorities named in D.T.S.D's paragraph 5 of 13th March, 1956, including in the covering letter the gist of this Branch's preceding paragraph.

6. Submitted.

A.S. Osley

DSH/PH/CCB.11

for HEAD OF MILITARY BRANCH,
17 March, 1956.

Propose to approve.

I suggest the first line of the table in para 3.3 might to avoid misunderstanding be amended to read

5 - 25 No significant effect. D.T.S.D & M.D.G. concur in this.

J.A. Carrow[?]
19 Mar 56

Approved as D.C.(R&D)

[signature]
for D.C.S. 20/3/56

SECRET

P.T.O.

SECRET

Report distributed under A.L. M/TSD 82/56 of 27th March, 1956 (copy enclosed).

2. Commodore, Special Squadron's 250614/March has been received, paragraphs 1 and 2 of which are answered by the despatch of the report referred to above.

3. Paragraphs 3 and 4 would appear to be matters for D.P.R and D.O.D. respectively and those departments are requested to remark.

[illegible signature]
for Hd. [illegible]
28.3.56.

D.P.R. proposes, with the concurrence of the scientists in DIANA and S.A.R.L., that the Radiological Safety Regulations in force for Operation MOSAIC (Joint Operational Plan - Section E) shall be deemed also to apply to DIANA and her company in so far as is appropriate, with the exception of paragraph 2.2.1 concerning the hazard from external beta and gamma radiation.

2. D.P.R. proposes further that the various levels specified by the A.W.R.E. MOSAIC regulations for external beta and gamma radiation, namely

(a) a lower integrated dose

(b) a higher integrated dose

and (c) a special higher integrated dose

shall be retained, but under the conditions of the following paragraph.

3. (a) <u>A Lower Integrated Dose</u> of up to 3r

This may be received by any of the ship's company for each event without further permission.

(b) <u>A Higher Integrated Dose</u> of up to 50 rep of which the gamma component must not exceed 10r

This dose may be received only in cases of necessity in order to recover vital records or information which might otherwise be lost and will require the personal permission of the Health Physics representative aboard DIANA (Mr. Thomas) after consultation with the Medical Officer.

Persons who receive up to the H.I.D. (in excess of the L.I.D.) shall not be deliberately exposed to a

/further

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Register No. T.S.D.82/56 Minute Sheet No. 3

further radiation dose in excess of the L.I.D. during the remainder of the Operation.

(c) A Special Higher Integrated Dose of up to 75 rep of which the gamma radiation component must not exceed 25r

This dose shall be applicable only in cases of extreme necessity and only to personnel who are not normally exposed to radiation, and then only with the express personal permission of Commodore Special Squadron after consultation with the Health Physics representative aboard DIANA and the Medical Officer.

Persons who receive up to the Special H.I.D. (in excess of the H.I.D.) shall not be exposed to further radiation during the remainder of the Operation.

4. D.P.R. understands that sufficient film badges will be available aboard DIANA for issue to any Special Parties who might receive radiation up to either of the Higher Integrated Doses. These badges will measure the beta dose (expressed in rep) as well as the gamma dose, and although these doses will not be known until after photographic development (by A.W.R.E. Health authorities) guidance will thereby be obtained upon the degree of subsequent exposure permissible to these individuals.

5. With reference to C.S.S.'s 250614Z March paragraph 3, the top dose rate is such that the total dose received as a result of the exposure is no greater than that specified by the appropriate level of paragraph 3 above. Allowance for decay of the activity during the period of exposure should be made by use of the radiac slide rule.

6. M.D.G. has been inserted in the marking for comment on paragraphs 1, 2 and 3 above.

B. C. Poole

for DIRECTOR OF PHYSICAL RESEARCH
3rd April, 1956

M.D.G. appreciates that in these infrequent, and very expensive, Operations it is reasonable that some slight risks should be incurred by personnel rather than that important records and observations should be lost. He accordingly does not dissent from D.P.R's proposals in his Minute of 3rd April.

2. It is presumed that the full beta dosage associated with the Special Higher Integrated Dose (S.H.I.D.) is likely in practice to be restricted to relatively small areas of skin, e.g. parts of the head and neck, and the hands and feet. In such a case the total volume of tissue irradiated would not be large enough to lead to any general illness.

3. The proviso that the S.H.I.D. should be limited to personnel not normally working with radiation should be insisted on. The principle of keeping the overall lifetime exposure of radiation workers as low as possible is important; and an extra 75r would be an appreciable burden.

4. The prospects of any long term effects from the S.H.I.D. are perhaps not very great. However, it would be as well to minimise them. Consequently, if it is practicable to select recipients for the S.H.I.D., older men should be chosen rather than young ones.

J F H Holford

for MEDICAL DIRECTOR GENERAL
5th April 1956

Subject to the concurrence of D. of D., D.O.D. agrees that DIANA should, if necessary, be decontaminated at Singapore rather than in Australia.

2. Referred to D. of D.

11 APR

J. Dunnachie-Cole

for DIRECTOR OF OPERATIONS DIVISION.
10th April, 1956.

AB/HMM

SECRET

Register No. T.S.D. 82/56 Minute Sheet No. 4.

D. of D. has no trained Dockyard personnel available in Singapore to undertake the decontamination of DIANA, if this should prove to be necessary. In 1953, however, the subject of Radio Active Contamination Organisation was given some consideration by C. in C. Far East Station, based on scientific information then available. On A.L. dated 13.8.53, M.O.1644/53 C. in C. F.E.S. was requested to reconsider these proposals further in the light of certain other information supplied, making use of facilities available. The outcome of this is not known to D. of D., but in any event such considerations would have little material influence on the task of decontaminating H.M.S. DIANA.

2. In the absence of Dockyard personnel suitably trained, it would therefore be necessary to resort to Naval personnel in this special instance and since the question of providing or earmarking a suitable anchorage and/or dry dock, in addition to the provision of the necessary personnel must be considered locally, it is proposed that this matter be referred to C. in C. F.E.S.

G. Hubback.

DIRECTOR OF DOCKYARDS.
18 April, 1956.

D OF D
18 APR 1956

Noted, concurring with D.P.R's proposals and with paragraph 2 of D of D's minute dated 18/4/1956. It is confirmed that the concurrence mentioned in the first line of D.P.R's minute has already been obtained.

2. Head of M Branch referred for reply to C.S.S. in the sense of Departmental remarks; a copy should be sent to DIANA. It seems that shortage of time makes it imperative to reply by signal, even though this will have to be a long one. YELLOW JACKET has been restored.

D.H. Crawford.

for DIRECTOR TACTICAL, SHIP REQUIREMENTS AND STAFF DUTIES DIVISION.
19th April, 1956.

Commodore, Special Squadron, in his 250614/March enclosed, seeks guidance on the levels of radiation to which the personnel, in particular the scientists, on board H.M.S. DIANA can be exposed ~~to radiation~~ during Operation MOSAIC. He also suggests that, should DIANA require decontamination beyond ships resources, she should proceed to Singapore rather than an Australian port.

2. The radiological safety regulations for the operation are set out in Section E of the MOSAIC Joint Operational Plan. D.P.R., with the concurrence of the Superintendent, Admiralty Research Laboratory and the scientists on board DIANA, suggests that these regulations be applied generally in DIANA's case, except that the paragraph dealing with the levels of beta and gamma radiation should be revised. The effect is a slight easing of the restrictions, thereby increasing, to a small degree, the risks involved. M.D.G., bearing in mind the importance of the operation and the need to recover valuable records which might otherwise be lost, agrees that the risks are acceptable. He stresses, however, the importance of keeping each man's overall lifetime exposure to radiation as low as possible and suggests that personnel likely to receive the Special Higher Integrated Dose of 75 rep should, where practicable, be chosen from older, rather than younger men.

3. Decontamination of H.M.S. DIANA

In the unlikely event of DIANA becoming so contaminated as to require dockyard assistance it will be advisable for the work to be carried out at Singapore, where there will be better facilities and more likelihood of obtaining R.N. personnel for the task should it prove impracticable to employ dockyard staff. In any event Singapore will be the nearest port with facilities for dealing with any sizeable job of this sort. It is proposed to ask C. in C. Far East Station what arrangements can be made. The question of whether the vessel can be sailed for that distance without danger to the crew must be decided on the advice of the medical officers on the spot.

4. The subject matter of the proposed reply to Commodore, Special Squadron (copy to DIANA) is such that a letter is perhaps preferable to a signal but in view of the shortage of time it is proposed to adopt the latter method.

5. Draft signals to Commodore, Special Squadron and C. in C. Far East Station are submitted.

A.S. Oxley

DSH/SM/CCB.11

for HEAD OF MILITARY BRANCH.
24 April, 1956.

Propose to approve as amended

W.J. Gendell
for D.N.S. 25/4/56

Concur.
26/4/56

SECRET

(777) Wt. 40423/P6184 40M (8) 9/54 S.E.R. Ltd. Gp. 647

Register No. TSD 82/56 Minute Sheet No. 5

Concur

RE.

28.4.56.

Approved

[illegible]

D2'OL

1/5/56

Signals made. Copies enclosed.

[illegible] Hall

for HD [illegible]

2.5.56.

Distribution on overleaf.

SECRET

TOP SECRET
MESSAGE

OUT

CS(R)1 - RECORDS REVIEW

SENSITIVITY NOTE

Covering
TOP SECRET / GUARD

PART I

To Sensitivity Reviewer

The attached piece - Reference TSD 82/56 Subject Operation Mosaic
-Stationing of DIANA for Scientific Observation / fall out......

is referred for examination and advice on the action to be taken.

Questionable material has been flagged. (~~Delete if inappropriate~~).-

Comment:

NUCLEAR CONTENT

Signed [signature] Date 31/1/83.
(A.H. YOULDON)

PART II

Sensitivity Reviewer's Comments

Nuclear Sensitive. Test weapon yield may be deduced from data.

Action is required as at .d. below.

a. Release piece to PRO for normal opening.

b. Remove and dispose of sensitive material as indicated in comments above: to be reviewed again in 19...... . Release remainder of piece to PRO for normal opening.

c. Close piece for ..... years from date of creation (latest date of contents of a file, or date of publication of a volume) and release, on this basis, to PRO.

(b and c: Lord Chancellor's Instrument, or approval, to be applied for, where appropriate.)

d. Withhold from PRO. Review again in 19.93. .

e. Other action (state) ....

....

....

With reference to any related correspondence ....

Signed [signature] Date 18/1/..

Distribution overleaf.

TOP SECRET

MESSAGE

DISTRIBUTION OF THIS MESSAGE IS TO BE LIMITED TO THOSE OFFICERS WHO ARE [illegible]

FROM Admiralty Date:— [illegible]

1.5.56.

To C.S.S.

INFO: H.M.S. DIANA.

WARNING

NO UNCLASSIFIED REPLY OR REFERENCE IF D.T.G. IS QUOTED

GUARD.

EXCLUSIVE

Your 250614/March. not to DIANA

Instructions in A.L. M/TSD.82/56 of 27.3.56 and MJOP/E will apply except that para 3.2 of Appendix to former and paragraph 2.2.1 of latter may, in DIANA's special circumstances, be modified as follows.

2. The following levels of Radiation are allowed in the circumstances shown.

(a) Lower Integrated Dose (up to 3r)

Any of ship's company on each occasion without special permission.

(b) Higher Integrated Dose (up to 50 rep of which gamma content must not exceed 10r)

Only in cases where necessary to obtain vital records or information which might otherwise be lost. Approval of DIANA's Health Physics Officer and Medical Officer required. Persons not to be exposed to further radiation above L.I.D. for remainder of operation.

(c) Special Higher Integrated Dose (up to 75 rep of which gamma content must not exceed 25r)

Only in extreme necessity and then to persons not normally exposed to radiation. Approval of C.S.S. and DIANA's Health Physics Officer and Medical Officer required. Persons not to be exposed to further radiation for remainder Operation.

NOTE: Decay of radiation activity will be allowed for by reference to radiac slide rule.

3. Although maximum S.H.I.D. unlikely to have long term effect it is emphasised that overall lifetime radiation exposure of personnel must be kept as low as possible. If practicable to select recipients, older rather than younger men should be chosen.

4. Your paragraph 3. Total dose must not exceed levels in paragraph 2 above.

5. Your paragraph 4. Agree, but care must be taken that additional time on passage does not expose personnel to radiation in excess of paragraph 2 above. C. in C. F.E.S. is being consulted.

[illegible]1736[illegible]

TOO HEAD OF MILITARY BRANCH, (Ext. 902)

Distribution overleaf.

TOP SECRET

2nd S.L.(2)
Controller
V.C.N.S. (2)
D.C.N.S.
D.C.(R.& D)
D.T.S.D.
(TSD.82/56)
D.P.R.
M.D.G.
D.O.D.(4)
D.C.
Head of M. (6)

?GVA/19.

TOP SECRET

OUT

TOP SECRET
MESSAGE

DISTRIBUTION OF THIS MESSAGE IS TO BE LIMITED TO THOSE OFFICERS WHO ARE CONCERNED WITH ITS CONTENTS

Date :— 011737Z

FROM Admiralty

1.5.56.

To C. in C. F.E.S.

INFO: C.S.S.

WARNING

NO UNCLASSIFIED REPLY OR REFERENCE IF D.T.G. IS QUOTED

GUARD

In unlikely event of DIANA requiring decontamination beyond ships resources it may be necessary to proceed Singapore rather than Australian port.

2. Request you report what arrangements can be made including use of R.N. personnel if Dockyard labour not suitable

011737Z

HEAD OF MILITARY BRANCH,
(Ext. 902)

2nd S.L.
Controller
V.C.N.S.(2)
D.C.N.S.
D.C.(R & D)
D.T.S.D.
(TSD.82/56)
D.P.R.
D.O.D.
D.C.
M.D.G.
Head of M.(6)

?GVA/19

TOP SECRET

TOP SECRET

MESSAGE

DISTRIBUTION OF THIS MESSAGE IS TO BE LIMITED TO THOSE OFFICERS WHO ARE CONCERNED WITH ITS CONTENTS

250614Z March

From: Commodore Special Squadron

Date: 25.3.56.

Recd: 0951

To: Admiralty

RECIRCULATION AT REQUEST OF D.G.N.S. OFFICE 26.3.56.

W A R N I N G

NO UNCLASSIFIED REPLY OR REFERENCE IF D.T.G. IS QUOTED

GUARD

Since DIANA's scientific tasks in Mosaic are responsibility of Admiralty not A.W.R.E., request

(a) Specification of radiation levels to which her company may be exposed.

(b) Agreed medical brief.

2. Understand from A.W.R.E. that proposals for DIANA's tasks seem quite reasonable.

3. Possible that scientists in DIANA may request permission to undertake work involving dosage higher than upper limits specified. Under these conditions I would like ruling on top dosage rate permitted for them if this should be necessary.

4. In unlikely event of DIANA requiring decontamination beyond ship's resources consider she should proceed Singapore rather than Australian Port.

250614Z

D.G.N.S. (2)
D.C. (R. and D.)
D.T.S.D.
Head of M. (6) for action
D.P.R.
D.O.D. (4)

NG.19.64

TOP SECRET

BY AIR SECRET GUARD

Any further communication should be addressed to -
The Secretary of the Admiralty,
London, S.W.1.
quoting "M/T.S.D. 82/56"

Admiralty,
S.W.1.

13th April, 1956.

Commodore, Special Squadron. (12 copies)

Copies to: Commander-in-Chief, Far East Station.
Captain, H.M.S. PHOENIX.
Commanding Officer, H.M.S. DIANA.
Superintendent, Admiralty Research Laboratory.
Director, Atomic Weapons Research Establishment, Aldermaston. (5 copies)

In continuation of Admiralty Letter dated 27th March, 1956, I am to inform you that further information is now available about the means of determining the station to be adopted by H.M.S. DIANA during Operation MOSAIC.

2. The intention is that the weapon yields should be revised at intervals up to the time of firing. To provide a quick and simple means of calculating H.M.S. DIANA's best position the enclosed three graphs have been prepared. The method of using the graphs is shown in the accompanying memorandum.

3. I am to request that these documents may be passed to Mr. Mathewman (A.W.R.E.) who will be responsible for predicting the fall-out pattern.

BY COMMAND OF THEIR LORDSHIPS,

Copies to: V.C.N.S., Controller, D.C.N.S., D.C. (R. & D.), A.C.N.S.(W), A.C.N.S., N.A.1.S.L., D.N.E., D.O.D., D.N.C., D.P.R., E. in C., D.O.R., M.D.G., D.T.S.D., M.39 (1)

DSH/CSM/OCB.11

SECRET GUARD

DPR/BWS/90/56

Operation MOSAIC - Fall-out Observations

Procedural Details for the Stationing of H.M.S. DIANA and the Scientific Whaler

1. Introduction

1.1 In an earlier paper (DPR/BWS/78/56) it was decided (para. 6.1) 'that DIANA shall be at that distance from Ground Zero at which the hypothetical peak total dose in an infinite field would be 5 roentgens'.

1.2 This distance will depend on the yield of the weapon and the prevailing weather. The variation of temperature and humidity with height will determine the height to which the cloud will rise. This is likely to be one of two values (for a given yield) depending on whether or not water vapour condenses in the cloud. The direction and speed of the mean wind up to the height of the cloud will determine the direction and distribution of fall-out. The latter depends primarily on the yield of the weapon and on σ_θ, the angular standard deviation of the distribution of deposited activity, which can be estimated from the prevailing wind structure.

1.3 For a given yield and height of cloud, the distance for a total dose of 5 roentgens depends principally upon σ_θ and only to a slight extent upon the mean wind speed.

1.4 In DPR/BWS/78/56 a table of recommended distances for DIANA was given for various values of σ_θ using the best estimates of the yield available at the time (March 9th) and assuming a mean wind speed of 30 knots. Two sets of values were given for each burst corresponding to a condensed and an uncondensed cloud respectively.

1.5 It is likely that the estimates of probable yield will change before the event necessitating a revision of the data in the table of DPR/BWS/78/56.

1.6 Accordingly, three graphs have been prepared (attached) for three heights of cloud of 10, 20 and 40 thousand feet respectively. (The variation with height between these values is small). On each graph are drawn ten curves, each corresponding to a given estimated yield. Values range from 5-120 kT. The curves show the required distance for DIANA as a function of σ_θ^2. A single mean wind of 30 knots has been assumed since the total dose is almost independent of wind speed.

2. Discussion of Procedure

2.1 The primary responsibility of Messrs. Matthewman and Macdougall is to predict the fall-out pattern to be expected under the conditions prevailing at the proposed moment of firing. Firing will not take place unless the expected pattern is over a safe area.

2.2 To this end values of σ_θ^2 as a function of distance and the probable height of the cloud will be continually evaluated from the available meteorological data. These values will be determined using an estimated height of cloud based upon the most dangerous (i.e. greatest) reasonably probable value for the yield.

2.3 To determine the best position for DIANA it is desirable to use the most probable yield instead of the <u>greatest</u> reasonably probable yield required for safety considerations.

2.4 However the dependence of σ_θ^2 upon cloud height is likely to be relatively small, and as there will not be sufficient time to make a separate series of calculations of σ_θ^2 using a cloud height based on the smaller most probable yield, the values of σ_θ^2 already calculated will be acceptable for the determination of DIANA's distance.

2.5 The revised value of cloud height based on the most probable yield can, however, be used in conjunction with the calculated values of σ_θ^2 made for safety purposes, to determine DIANA's distance using the attached graphs. The inconsistency involved here is small and is acceptable. This revised value of cloud height may be determined by a simple re-estimate (e.g. by use of the $W^{\frac{1}{4}}$ scaling law).

2.6 The direction of the fall-out is to be determined by the direction of the mean wind to the bottom of the cloud (the height of which is to be based on the most probable yield - see previous p ragraph). Any correction for non-local winds which may be available should be applied.

2.7 It is possible that, during the continuing period of review before firing, a clear-cut decision as to whether or not the cloud will condense will be difficult. In such a case there will be two alternative positions forecast for DIANA. Commodore Special Squadron should be informed of the two alternatives and be given guidance on their relative probabilities. Final decision as to which to recommend will rest with C.S.S.

2.8 DIANA should be continually informed by C.S.S. of her best position during the Stand-by Period when routine evaluation of σ_θ^2 is being made for safety purposes.

2.9 The value of σ_θ^2 at the recommended distance of DIANA and estimated height of cloud based on most probable yield are to be transmitted to her at the same time as her recommended position. This will enable the Health Physics representative (Mr. Thomas) to check the position from the graphs available to him.

2.10 After firing, such arrangements as might be made to obtain immediate post detonation measurements of height of cloud and yield for purposes of directing the aircraft traverses should be used to provide revised estimates of direction and distance for DIANA.

2.11 The tracking of the radio-active fall-out at or near sea level (paragraph 10.5 of DPR/BWS/78/56) will not be possible.

3. Summary of Recommended Procedures (This supersedes the Conclusions and Recommendations of DPR/BWS/78/56).

3.1 Whenever a computation of σ_θ^2 at various distances has been completed for safety purposes by Matthewman and Macdougall, the values shall be plotted by them on one of the graphs attached.

3.2 The graph chosen shall be the one corresponding most nearly to the estimated height of the cloud centre based on the most probable yield.

3.3. The estimated height of the cloud centre based on the most probable yield shall be derived in a simple manner (e.g. by the use of the $W^{\frac{1}{4}}$ scaling law) from the estimated height of the cloud centre already computed for safety purposes based on the greatest reasonably probable yield.

3.4 The intersection of the plotted curve of σ_θ^2 against distance with the curve on the graph corresponding to the latest available estimate of yield will give the best estimate of the distance of DIANA from Ground Zero.

3.5 The recommended direction of DIANA from Ground Zero shall be determined by the direction of the mean wind to the bottom of the cloud, the height of which is to be based on the most probable yield. Any correction for non-local winds which may be available shall be applied.

3.6 In case of uncertainty C.S.S. should be informed of the two alternative positions and given guidance as to their relative likelihood.

3.7 DIANA should be kept continually informed of her best position and the estimated time of arrival of fall-out*. The value of σ_θ^2 at her best position and the estimated height of cloud based on the most probable yield shall also be transmitted as a check for the Health Physics representative.

3.8 In order that the Health Physics representative aboard DIANA may be able to check satisfactorily the data sent him, it will be necessary for him to ascertain the likely yields of the weapons beforehand.

3.9 Revised estimates of the best position should be sent to DIANA after detonation in so far as post-detonation data of yield and cloud height become available.

3.10 The position of the dropping of the unmanned whaler should be as close-in as possible, but it is likely to be governed by the need for DIANA subsequently to reach her own station in time. The exact location of the whaler is therefore left to the discretion of the appropriate naval authorities in consultation with Mr. Thomas.

3.11 Estimates of the expected direction of fall-out were made in paragraph 7 of DPR/BWS/78/56 and may still be taken as a rough guide.

3.12 Should DIANA, in spite of all precautions, find herself in an unacceptable high radiation field it is recommended that she steam at full speed in that direction at 45° to the bearing of Ground Zero which is most nearly opposed to the surface wind.

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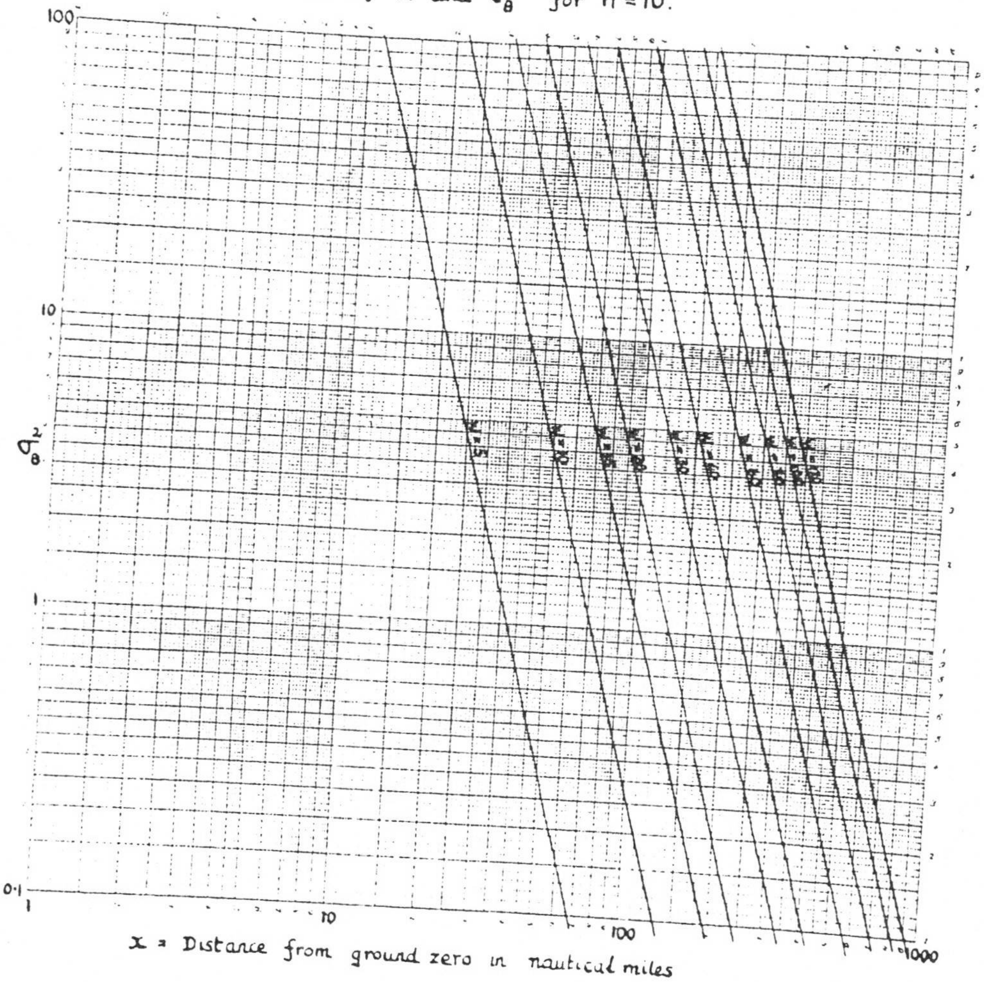
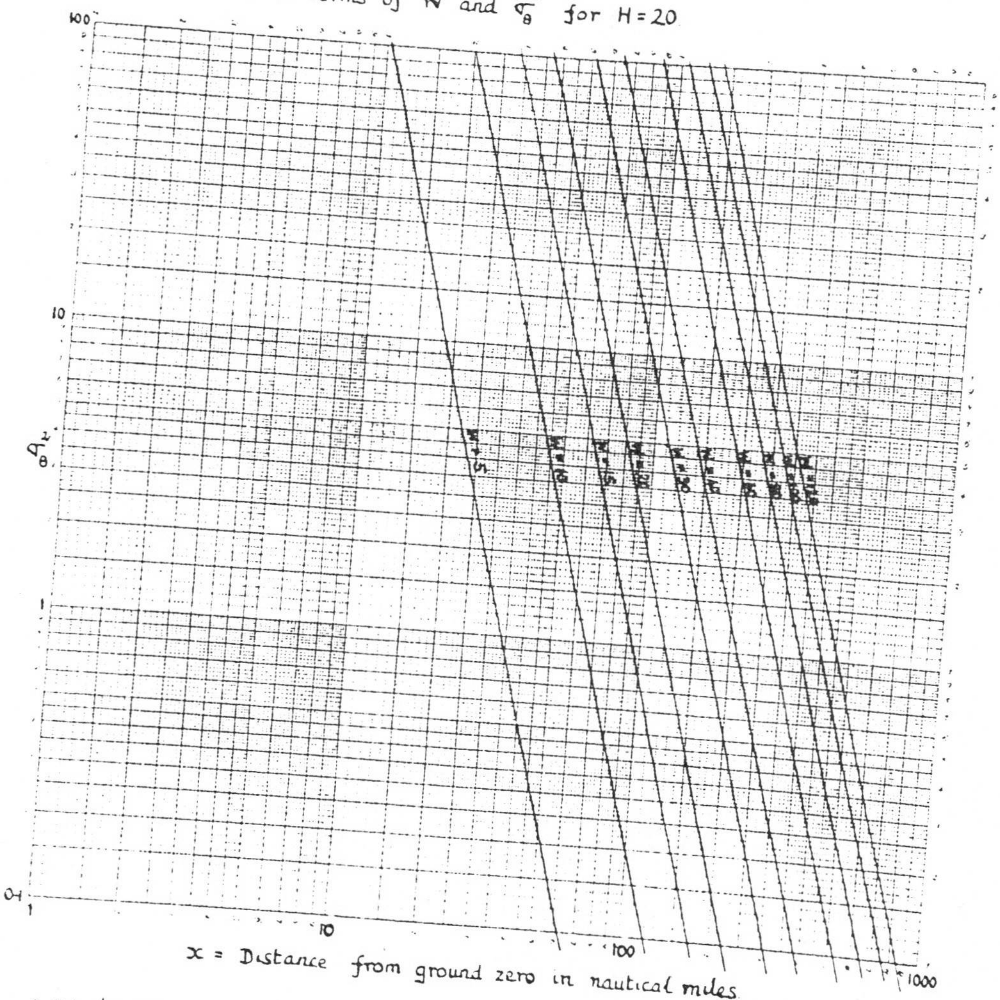
* (This will be based on the appropriate mean wind speed and distance and will refer to the time of arrival of the peak activity - not the time of arrival of the first activity).

OPERATION MOSAIC Diagram giving recommended position of H.M.S. DIANA in terms of W and σ_θ^2 for H = 10.



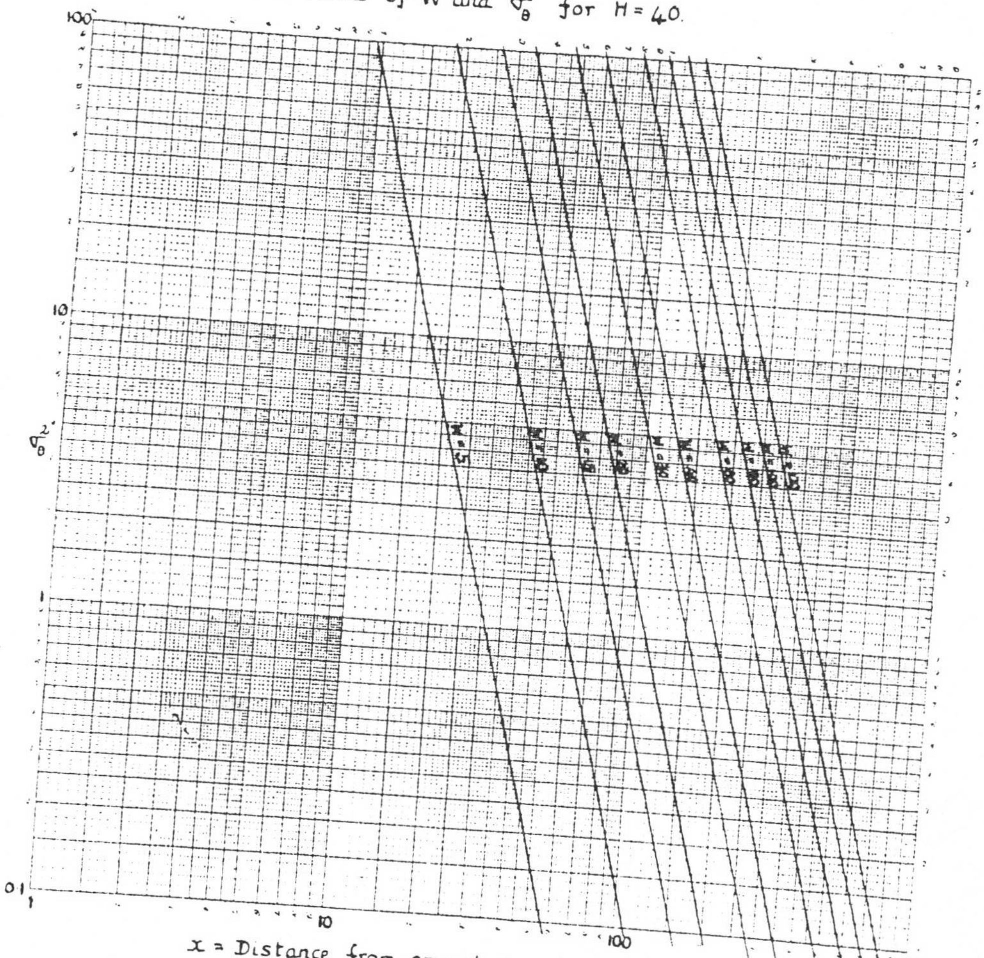
A.R.L./C 791

OPERATION MOSAIC Diagram giving recommended position of H.M.S DIANA in terms of W and σ_θ^2 for H = 20



A.R.L./C 791

OPERATION MOSAIC · Diagram giving recommended position of H.M.S. DIANA in terms of W and σ_θ^2 for H = 40.



x = Distance from ground zero in nautical miles

A.R.L./C 791

REFERENCE SHEET

ADMIRALTY

From: Director of Physical Research
Sanctuary Buildings,
20 Great Smith Street,
London, S.W.1.

Ref. No.: DPR/BWS/89/56

Dated: 29th March, 1956

To: D.T.S.D.
(Attention of Cdr. D.A. Lawford)

Copy to: Mr. E.P. Hicks, A.W.R.E.
(with enclosure but excluding graphs)
Mr. I. Maddock, A.W.R.E.
(with enclosure but excluding graphs)
Mr. E.M.L. Beale, A.R.L. "
Dr. S.C. Ellis, A.R.L. "

Operation MOSAIC - Fall-out Observations

Detailed Procedure

In DPR/BWS/78/56 were given the reasons for stationing DIANA at a position where the dose to personnel below deck in an adequately pre-wetted and washed down ship was likely to be ~~xf~~ about 0.3 roentgen.

2. A table was included which gave the recommended distances from both events according to the prevailing meteorological conditions and the best assumptions that could then be made of the weapon yields.

3. It has since been learned that the weapon yields are likely to be revised at intervals up to the time of firing.

4. On Friday, 23rd March, 1956, a meeting was held at A.W.R.E. to discuss the procedure to be adopted for forecasting the best position for DIANA. Messrs. Hicks, Matthewman and Macdougall (A.W.R.E.), Mr. Beale (A.R.L.) and Dr. B.W. Soole (D.P.R.) were present.

5. Mr. Beale produced three graphs on the basis of the condition of paragraph 1 (above) with the aid of which a simple and rapid estimation of DIANA's best position can be made.

6. The procedure to be adopted and the method of using the graphs were discussed in detail and the conclusions are set out in the attached DPR/BWS/90/56.

7. It is suggested that copies of the attached DPR/BWS/90/56 be sent to all recipients of the earlier document (originally DPR/BWS/78/56).

8. Thirtyeight copies of the three graphs are enclosed. It is requested that twelve sets of the three graphs be sent to C.S.S. (Attention of Mr. Matthewman) for use at the trial and single sets to all others.

for DIRECTOR OF PHYSICAL RESEARCH

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for DIRECTOR OF PHYSICAL RESEARCH

DPR/BWS/90/56

Operation MOSAIC - Fall-out Observations

Procedural Details for the Stationing of H.M.S. DIANA and the Scientific Whaler

1. Introduction

1.1 In an earlier paper (DPR/BWS/78/56) it was decided (para. 6.1) 'that DIANA shall be at that distance from Ground Zero at which the hypothetical peak total dose in an infinite field would be 5 roentgens'.

1.2 This distance will depend on the yield of the weapon and the prevailing weather. The variation of temperature and humidity with height will determine the height to which the cloud will rise. This is likely to be one of two values (for a given yield) depending on whether or not water vapour condenses in the cloud. The direction and speed of the mean wind up to the height of the cloud will determine the direction and distribution of fall-out. The latter depends primarily on the yield of the weapon and on σ_θ , the angular standard deviation of the distribution of deposited activity, which can be estimated from the prevailing wind structure.

1.3 For a given yield and height of cloud, the distance for a total dose of 5 roentgens depends principally upon σ_θ and only to a slight extent upon the mean wind speed.

1.4 In DPR/BWS/78/56 a table of recommended distances for DIANA was given for various values of σ_θ using the best estimates of the yield available at the time (March 9th) and assuming a mean wind speed of 30 knots. Two sets of values were given for each burst corresponding to a condensed and an uncondensed cloud respectively.

1.5 It is likely that the estimates of probable yield will change before the event necessitating a revision of the data in the table of DPR/BWS/78/56.

1.6 Accordingly, three graphs have been prepared (attached) for three heights of cloud of 10, 20 and 40 thousand feet respectively. (The variation with height between these values is small). On each graph are drawn ten curves, each corresponding to a given estimated yield. Values range from 5-120 kT. The curves show the required distance for DIANA as a function of σ_θ^2. A single mean wind of 30 knots has been assumed since the total dose is almost independent of wind speed.

2. Discussion of Procedure

2.1 The primary responsibility of Messrs. Matthewman and Macdougall is to predict the fall-out pattern to be expected under the conditions prevailing at the proposed moment of firing. Firing will not take place unless the expected pattern is over a safe area.

2.2 To this end values of σ_θ^2 as a function of distance and the probable height of the cloud will be continually evaluated from the available meteorological data. These values will be determined using an estimated height of cloud based upon the most dangerous (i.e. greatest) reasonably probable value for the yield.

2.3 To determine the best position for DIANA it is desirable to use the most probable yield instead of the greatest reasonably probable yield required for safety considerations.

/2.4

2.4 However the dependence of σ_θ^2 upon cloud height is likely to be relatively small, and as there will not be sufficient time to make a separate series of calculations of σ_θ^2 using a cloud height based on the smaller most probable yield, the values of σ_θ^2 already calculated will be acceptable for the determination of DIANA's distance.

2.5 The revised value of cloud height based on the most probable yield can, however, be used in conjunction with the calculated values of σ_θ^2 made for safety purposes, to determine DIANA's distance using the attached graphs. The inconsistency involved here is small and is acceptable. This revised value of cloud height may be determined by a simple re-estimate (e.g. by use of the $W^{1/4}$ scaling law).

2.6 The direction of the fall-out is to be determined by the direction of the mean wind to the <u>bottom</u> of the cloud (the height of which is to be based on the most probable yield - see previous paragraph). Any correction for non-local winds which may be available should be applied.

2.7 It is possible that, during the continuing period of review before firing, a clear-cut decision as to whether or not the cloud will condense will be difficult. In such a case there will be two alternative positions forecast for DIANA. Commodore Special Squadron should be informed of the two alternatives and be given guidance on their relative probabilities. Final decision as to which to recommend will rest with C.S.S.

2.8 DIANA ~~is to~~ should be continually informed by C.S.S. of her best position during the Stand-by Period when routine evaluation of σ_θ^2 is being made for safety purposes.

2.9 The value of σ_θ^2 at the recommended distance of DIANA and estimated height of cloud based on most probable yield are to be transmitted to her at the same time as her recommended position. This will enable the Health Physics representative (Mr. Thomas) to check the position from the graphs available to him.

2.10 After firing, such arrangements as might be made to obtain immediate post detonation measurements of height of cloud and yield for purposes of directing the aircraft traverses should be used to provide revised estimates of direction and distance for DIANA.

2.11 The tracking of the radio-active fall-out at or near sea level (para. 10.5 of DPR/BWS/78/56) will not be possible.

3. <u>Summary of Recommended Procedures</u> (This supersedes the Conclusions and Recommendations of DPR/BWS/78/56).

3.1 Whenever a computation of σ_θ^2 at various distances has been completed for safety purposes by Matthewman and Macdougall, the values shall be plotted by them on one of the graphs attached.

3.2 The graph chosen shall be the one corresponding most nearly to the estimated height of the cloud centre based on the <u>most probable</u> yield.

3.3 The estimated height of the cloud centre based on the <u>most probable</u> yield shall be derived in a simple manner (e.g. by the use of the $W^{1/4}$ scaling law) from the estimated height of the cloud centre already computed for safety purposes based on the <u>greatest</u> reasonably probable yield.

3.4 The intersection of the plotted curve of σ_θ^2 against distance with the curve on the graph corresponding to the latest available estimate of yield will give the best estimate of the distance of DIANA from Ground Zero.

/3.5

3.5 The recommended direction of DIANA from Ground Zero shall be determined by the direction of the mean wind to the <u>bottom</u> of the cloud, the height of which is to be based on the most probable <u>yield</u>. Any correction for non-local winds which may be available shall be applied.

3.6 In case of uncertainty C.S.S. ~~shall~~ should be informed of the two alternative positions and given guidance as to their relative likelihood.

3.7 DIANA ~~shall~~ should be kept continually informed of her best position and the estimated time of arrival of fall-out.* The value of σ_0 at her best position and the estimated height of cloud based on the most probable yield shall also be transmitted as a check for the Health Physics representative.

3.8 In order that the Health Physics representative aboard DIANA may be able to check satisfactorily the data sent him, it will be necessary for him to ascertain the likely yields of the weapons beforehand.

3.9 Revised estimates of the best position ~~shall~~ should be ~~provided~~ sent to DIANA after detonation in so far as post-detonation data of yield and cloud height become available.

3.10 The position of the dropping of the unmanned whaler should be as close-in as possible, but it is likely to be governed by the need for DIANA subsequently to reach her own station in time. The exact location of the whaler is therefore left to the discretion of the appropriate naval authorities in consultation with Mr. Thomas.

3.11 Estimates of the expected direction of fall-out were made in paragraph 7 of DPR/BWS/78/56 and may still be taken as a rough guide.

3.12 Should DIANA, in spite of all precautions, find herself in an unacceptably high radiation field it is recommended that she steam at full speed in that direction at 45° to the bearing of Ground Zero which is most nearly opposed to the surface wind.

---

* (This will be based on the appropriate mean wind speed and distance and will refer to the time of arrival of the peak activity - not the time of arrival of the first activity).

SECRET
GUARD

Copies to:- V.C.N.S., Controller, D.C.N.S., D.C.(R.& D.), A.C.N.S.(W), A.C.N.S., N.A.1 S.L., D.N.E., D.O.D., D.N.C., D.P.R., E.in C., D.O.R., M.D.G., D.T.S.D.

Any further communication should be addressed to -

The Secretary of the Admiralty,
London, S.W.1

quoting "M/TSD.82/56"

WHItehall 9000
Extension 902

Admiralty, S.W.1.

27 March, 1956.

Commodore, Special Squadron.

Copies to:- Commander-in-Chief, Far East Station.
Captain, H.M.S. PHOENIX.
Commanding Officer, H.M.S. DIANA.
Superintendent, Admiralty Research Laboratory.
Director, Atomic Weapons Research Establishment, (5 copies).

I am to inform you that Their Lordships have been considering what guidance can be given about the station H.M.S. DIANA and an unmanned whaler should take up during Operation MOSAIC (Admiralty message 151246/December, 1955 refers).

--- 2. I am accordingly to forward the enclosed paper, written by the Director of Physical Research, in collaboration with the Atomic Weapons Research Establishment, and based on a study made by the Admiralty Research Laboratory.

3. This paper represents the most up-to-date appreciation of the factors involved in MOSAIC and its recommendations have been agreed jointly by the Admiralty and the Atomic Weapons Research Establishment.

4. I am to add, however, that this report does not affect your normal responsibility for the safety of the ship and her company.

BY COMMAND OF THEIR LORDSHIPS,

Sgd. A. S. OGLEY

DSH/BLD/CCB.11

SECRET
GUARD

DPR/BWS/78/56

OPERATION MOSAIC - FALL-OUT OBSERVATIONS

Recommendations Concerning the Stationing of H.M.S. DIANA and the Scientific Whaler

1. Introduction

1.1 The original suggestion (meeting at A.W.R.E. 28th July, 1955) was that two observation ships might be used at distances of 200 miles and 400 miles respectively. The radiological hazard for G1 was estimated by A.W.R.E. to be:-

Distance (Miles)	Fall-Out Intensity (mc/m^2)	'Dose-Rate' at 1 hr. (r/hr)	Time of Arrival (hrs.)	Max. Integrated Dose (to infinity) (r)
200	8	1.0	H + 10	3.3
400	1.3	0.3	H + 20	0.9

1.2 When it became apparent that only one ship would be available it was decided that observations should be made at the shorter of the two distances, namely, at 200 miles. However, the provision of an unmanned whaler would enable additional measurements to be made much closer in. It was clearly desirable to obtain as much information as possible concerning the properties of fall-out at a shorter distance where it was capable of producing casualties. The closeness of the whaler was limited by the need for DIANA to steam from the whaler station to her own station in time to receive fall-out herself, and a position at 50 miles for the whaler was tentatively agreed.

2. Reasons for Choosing a Station as Close as Possible Consistent with Safety

2.1 The estimated progress of the radioactive cloud will be based largely upon meteorological data obtained immediately before firing in the region of the burst. Non-local winds may be expected to carry the contamination away from the predicted direction by a distance proportional to the square of the distance from ground zero. The angular error due to this will therefore increase linearly with distance.

2.2 The higher activity of fall-out at shorter distances means that if the ship is off the central path of the fall-out the marginal activity is more likely to have a useful level of radiation.

2.3 The time of passage of the fall-out is roughly proportional to the distance of the point of observation. Since it is hoped to close-down one engine-room during the passage of fall-out, any reduction of this time will considerably ease the problem of endurance of engine-room personnel.

2.4 The characteristics of the fall-out are likely to vary with distance. By fitting an unmanned whaler with a duplicate set of instruments and stationing her close-in where there is likely to be a casualty-producing level of radiation, valuable information will be obtained. It has not been found possible, however, to fit the whaler with automatic water sampling equipment. It is therefore desirable that DIANA, who will be so fitted, shall be stationed close in to obtain radio-active sea-water samples which will be as representative as possible of those in an area of hazardous operational fall-out.

/3.

3. Safety Considerations

3.1 The other effects of the explosions (blast, heat, gamma and neutron radiations) will all be negligible hazards at distances down wind compared with the danger from fall-out.

3.2 The maximum permissible levels of external radiation for Operation MOSAIC have been laid down as follows (Joint Operational Plan Section E p. 6, para. 2.2):-

	r	When Allowed	Remarks
Normal Working Rate	0.3	Once a week indefinitely	-
Lower Integrated Dose	3	Where necessary for the smooth running of the Operation.	No further exposure until average from beginning of Operation is down to N.W.R.
Higher Integrated Dose	10	Where necessary to recover vital records or information which might otherwise be lost.	As above.
Special Higher Integrated Dose	25	Applicable only in cases of extreme necessity and only to personnel who are not normally exposed to radiation.	No further exposure to radiation for three years.

3.3 The following table lists the probable early injurious effects on human beings (apart from genetic effects) to be expected from acute external doses of X or gamma rays over the whole body when received over a short period of time of the order of a day or less (U.S. Atomic Energy Commission quoted in "The Protection of Workers Against Ionizing Radiations", International Labour Office, August, 1955):-

Acute Dose (r)	Probable Effect
0-25	No significant effect.
25-50	Possible blood changes but no serious injury.
50-100	Blood cell changes; some injury; no disability.
100-200	Injury; possible disability.
200-400	Injury and disability certain; death possible.
400	Fatal to 50 per cent
600 or more	Fatal, probably to 100 per cent.

It will be seen from above that there appears to be no possibility of injury or even of blood changes after receipt of the Special Higher Integrated Dose.

4. Most Probable Dose-Distance Relationship

4.1 A careful study spread over several months by E. M. L. Beale (A.R.L.)

/of all

of all the data available to the Atomic Weapon Research Establishment including the results of both British and American tests has resulted in a graph showing the most probable distribution of activity with distance from MOSAIC explosions G1 and G2 (see Beale's MOSAIC report Ref. No. ARL/R1/C791). The latest information concerning the characteristics of the weapons likely to affect this distribution has been made available by A.W.R.E. for this purpose.

4.2 Representative figures taken from the graphs are:-

Total Dose to Infinite Time (roentgens)

Distance (Miles)	G1	G2
10	200	760
15	90	350
20	50	200
30	23.5	90
50	8.5	33
100	2.25	8.5
150	1.0	3.8

These figures have been derived assuming certain meteorological conditions, namely a mean wind speed of 20 knots and an angular standard deviation for the distribution of the activity of 3 degrees. Furthermore, it has been assumed that the cloud rises to 30,000 ft. for G1 and 40,000 for G2.

4.3 Some uncertainty is attached to these figures because of the large numbers of variables and the lack of sufficient experimental data, but Beale considers that if the best estimates available at the time, of the height to which the cloud will rise, the mean wind speed and the angular standard deviation are put into his basic formulae the results are unlikely to be out by a factor of more than 10, and that an error of a factor of more than 100 can be considered virtually impossible unless the bomb fails to explode.

5. Protection Afforded by the Ship

5.1 The dose figures quoted above (para. 4.2) assume that the dose is received from an infinite plane source of contamination. In practice the largest area from which radiation could possibly be received is the horizontal weather deck of the ship, since material falling on the surface of the sea will sink sufficiently for its radiation to be completely cut off. Experiments by A.R.L. (J. H. Williams) have shown that whereas an infinite area uniformly contaminated with cobalt 60 (1 curie/sq. ft.) will produce a dose-rate of 368 r/hr at a position 3 ft. 6 ins. above the deck, the same density of activity on the deck of the frigate RAPID will produce a dose-rate of only 190 r/hr. i.e., a reduction of 52%.

5.2 The A.R.L. experiments also showed that at the least protected of the covered positions for which measurements were made in RAPID, namely, the Captain's Position on the enclosed Bridge, the dose-rate was reduced to 40% of what it was on the weather deck. Thus the combined effect of a limited surface contaminated by fall-out and the physical shielding of the ship will produce a protection factor of approximately $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$. A similar figure of $\frac{1}{4}$ will apply to the slightly less penetrating radiation received from the fall-out deposited on the weather deck of DIANA (which is comparable in area to that of RAPID).

/5.3

5.3 By adequate pre-wetting of the ship's exposed surface, followed by effective washdown, indications are that approximately 75% of the fall-out can be washed away, i.e., a further protection factor of $\frac{1}{4}$ is effective.

5.4 Thus, for personnel under cover, at sea, in a ship which is being adequately pre-wetted and washed down, protection factors of approximately $\frac{1}{4} \times \frac{1}{4} = 1/16$ are applicable.

6. Stationing of H.M.S. DIANA

6.1 From a consideration of the above protection factors and the radiation tolerance doses discussed above, it has been decided that DIANA shall be at that distance from ground zero at which the hypothetical peak total dose in an infinite field would be 5 roentgens. The following will then apply:-

Dose from an infinite field	5 r
Dose on deck	2.5 r
Dose below deck (no washdown)	≤ 1.25 r
Dose below deck (pre-wetting and washdown)	≤ 0.3 r

6.2 It should be noted that the dose to personnel below deck in an adequately pre-wetted and washed down ship is equal to the weekly dose at the Normal Working Rate.

6.3 It should also be noted that should, by an unfortunate mischance, Beale's curves be as much as 20 times too low, AND the pre-wetting and washdown procedures be inoperative, then the dose received by personnel just below the weather deck will be 20 x 1.25 r = 25 r which is no more than the Special Higher Integrated Dose.

6.5 The formula given by Beale relating

x the distance in nautical miles from ground zero

H the maximum height of the centre of the cloud above sea level in thousands of feet

$\bar{u}$ the speed of the mean wind to the centre of the cloud measured in knots

and σ_θ the angular standard deviation (in degrees) of the distribution of activity on the ground (or sea)

for the hypothetical peak total dose of 5 roentgens in an infinite field is

$$x^{1.95} \quad 29015\, H^{-0.25} \quad \bar{u}^{-0.05} \quad \sigma_\theta^{-1}$$

6.6 It is seen that the dependence of x upon the mean wind $\bar{u}$ is very slight. Consultation with Mathewman suggests that a mean wind speed of 30 knots is most likely to be typical of conditions at the time of firing and this value for the mean wind has been adopted for the subsequent calculations.

6.7 Dependence of the distance x upon the height of the cloud H is rather more than the dependence of the distance upon the mean wind discussed above. The height of the cloud, however, is likely to tend to one of two values, depending on whether or not meteorological conditions favour water condensation in the cloud as it rises. If condensation occurs, then the latent heat given up will make the cloud more buoyant and it is likely to rise to the tropopause. If not, the cloud may remain many thousands of feet lower. For this reason two heights of cloud, with and without

/condensation

condensation, are considered for both G1 and G2.

6.8 The distance x at which a dose of 5 roentgens will be received is most sensitive to variations of σ_θ, the angular standard deviation. It is understood that this will be evaluated for the prevailing conditions before firing. The distance at which it is recommended DIANA be stationed can be found from the following table for both G1 and G2 according to the appropriate value of σ_θ and whether or not it is considered that the cloud will condense. (The heights of the cloud for G1 are taken to be 16,000 ft. (uncondensed) and 30,000 ft. (condensed) and for G2, 20,000 ft. (uncondensed) and 40,000 ft. (condensed)).

TABLE OF RECOMMENDED DISTANCES FROM GROUND ZERO FOR H.M.S. DIANA IN NAUTICAL MILES

	G.1		G.2	
σ_θ	Dry Cloud	Condensed Cloud	Dry Cloud	Condensed Cloud
½	178	164	357	326
1	125	115	250	229
1½	101	94	203	186
2	88	81	175	160
2½	78	72	156	143
3	71	65	142	130
3½	66	61	131	120
4	61	57	123	112
4½	58	53	116	106
5	55	50	109	100
5½	52	48	104	95
6	50	46	100	91
6½	48	44	96	88
7	46	43	92	84
7½	44	41	89	81
8	43	40	86	79
8½	42	38	83	76
9	41	37	81	74
9½	39	36	79	72
10	38	35	77	70

Note: The figures given in the above table are, of necessity, based upon the best estimates of yield available at the time this paper was written (March, 1956). It is probable that these estimates are not final and that, before firing day, A.W.R.E. representatives on the operation will be able to provide improved estimates of yield, which may require modifications to be made to the distances given above.

7. The Expected Duration of Fall-Out

7.1 This is difficult to estimate accurately but it is more sensitive to variations in the mean wind speed than is the estimated distance for observation previously discussed.

7.2 However, the following figures for three values (two extreme and one mean) of σ_θ have been evaluated for G1 and G2 and refer to the time required for 95% of the fall-out to arrive.

/Estimated

Estimated Duration of Fall-Out

G.1

σ_θ \ $\bar{u}$	10	20	30	40	50
½	1 hr. 10 min.	30 min.	20 min.	17 min.	14 min.
3	2 hr. 40 min.	1 hr. 20 min.	50 min.	40 min.	30 min.
10	5 hr.	2 hr. 30 min.	1 hr. 40 min.	1 hr. 10 min.	1 hr.

G.2

σ_θ \ $\bar{u}$	10	20	30	40	50
½	2 hr. 20 min.	1 hr. 10 min.	50 min.	30 min.	30 min.
3	5 hr. 30 min.	2 hr. 40 min.	1 hr. 50 min.	1 hr. 20 min.	1 hr. 10 min.
10	9 hr. 50 min.	4 hr. 50 min.	3 hr. 20 min.	2 hr. 30 min.	2 hr.

7.3 Until the correct values of σ_θ and $\bar{u}$ are available for conditions at the time of firing, for preliminary planning, values of 3 degrees for σ_θ and 30 knots for $\bar{u}$ may be taken as the most probable. In these cases we have:

Most Probable Duration of Fall-out (95%) for G1 = 50 min.
Most Probable Duration of Fall-out (95%) for G2 = 1 hr. 50 min.

7.4 These times are intended as a rough guide only. They may be in error by a factor of two.

8. Recommended Procedure to Avoid Exceptionally Heavy Fall-Out

8.1 Should, in spite of all precautions, DIANA find herself in an unacceptably high radiation field it is recommended that she steam at full speed in that direction at 45° to the bearing of ground zero which is most nearly opposed to the surface wind.

9. Stationing of the Unmanned Scientific Whaler

9.1 The object of using the whaler is to obtain data as representative as possible of fall-out which would be capable of producing casualties aboard an unprepared ship caught in it under operational conditions.

9.2 The chief limitation on the closeness with which the whaler can be stationed appears to be an operational one, since it is essential that DIANA be on her own station in time to make all necessary preparations after having dropped the whaler. The exact location of the whaler should therefore be left to the discretion of the Commanding Officer, H.M.S. DIANA, in consultation with Mr. D. M. C. Thomas and other appropriate authorities at the time of the operation.

10. Conclusions and Recommendations

10.1 For accurate prediction of the best position at which to station DIANA it is essential to have last minute evaluation of σ_θ, the angular standard deviation in degrees of the expected distribution of the fall-out at sea level, of $\bar{u}$ the speed and direction of the mean wind to the centre of the cloud and of whether or not condensation is likely to occur in the cloud. From this data the recommended distance for the stationing of DIANA can be determined from the Table in paragraph 6.8. Distances are likely to be of the order of 65 miles for G1 and 130 miles for G2.

10.2 The bearing from ground zero will be determined by the direction of the mean wind.

10.3 The expected duration of fall-out can be determined from the Table in paragraph 7.2. Durations are likely to be of the order of 50 minutes for G1 and 1 hr. 50 mins. for G2.

10.4 The position of the dropping of the unmanned whaler is likely to be governed by the need for DIANA subsequently to reach her own station in time and is left for on-the-spot decision.

10.5 Subsequent to detonation it is desirable that the position of the radio-active fall-out at or near sea-level be tracked by survey aircraft in order to keep DIANA informed so that she may be able if necessary to steam along an arc to the best position.

SECRET GUARD TSD/N/112/56

ADMIRALTY

REFERENCE SHEET

From: Director of Physical Research	To: D.T.S.D. (Attention of Cdr. D.A. Lawford).
Ref. No.: DPR/BWS/79/56	Copy to: Mr. I. Maddock, A.W.R.E.
Dated: 9th March, 1956	Mr. E.M.L. Beale, A.R.L.

Operation MOSAIC - Fall-out Observations

In accordance with the decision taken at the meeting held by D.T.S.D. on February 8th (paragraph 4 of the minutes) Mr. E.M.L. Beale of A.R.L. who has specialised in the study of fall-out from atomic explosions, has, at the request of D.P.R., made a special study of the problem of estimation of fall-out for the particular circumstances of Operation MOSAIC.

2. Mr. Beale has had the full co-operation of the appropriate authorities at A.W.R.E., and all relevant data has been placed at his disposal. His findings have been embodied in A.R.L. Report ARL/R1/C791, a copy of which will be sent to D.T.S.D. in due course.

3. As a result of this study, D.P.R. has produced a paper DPR/BWS/78/56 attached entitled "Recommendations Concerning the Stationing of H.M.S. DIANA and the Scientific Whaler". This has been discussed in detail with Beale, Thomas and Ellis (A.R.L.) who are in full agreement.

4. A draft copy has also been seen by Mr. I. Maddock, A.W.R.E. who confirms that it fulfils the requirement of an agreed A.W.R.E./D.P.R. recommendation.

5. Mr. Maddock however, is anxious that it is made clear to the Commodore Special Squadron that the safety of DIANA is an Admiralty responsibility and as such comes outside the immediate concern of the A.W.R.E. Health authorities at the time of the Operation.

B. L. Poole.

for DIRECTOR OF PHYSICAL RESEARCH

SECRET GUARD

DPR/BWS/78/56

Operation MOSAIC - Fall-out Observations

Recommendations Concerning the Stationing of H.M.S. DIANA and the Scientific Whaler

1. Introduction

1.1 The original suggestion (meeting at A.W.R.E. 28th July, 1955) was that two observation ships might be used at distances of 200 miles and 400 miles respectively. The radiological hazard for G1 was estimated by A.W.R.E. to be:-

Distance (Miles)	Fall-Out Intensity (mc/m^2)	'Dose-Rate' at 1 hr. (r/hr)	Time of Arrival (hrs.)	Max. Integrated Dose (to infinity) (r)
200	6	1.0	H + 10	3.3
400	1.3	0.3	H + 20	0.9.

1.2 When it became apparent that only one ship would be available it was decided that observations should be made at the shorter of the two distances, namely at 200 miles. However, the provision of an unmanned whaler would enable additional measurements to be made much closer in. It was clearly desirable to obtain as much information as possible concerning the properties of fall-out at a shorter distance where it was capable of producing casualties. The closeness of the whaler was limited by the need for DIANA to steam from the whaler station to her own station in time to receive fall-out herself, and a position at 50 miles for the whaler was tentatively agreed.

2. Reasons for Choosing a Station as Close as Possible Consistent with Safety

2.1 The estimated progress of the radioactive cloud will be based largely upon meteorological data obtained immediately before firing in the region of the burst. Non-local winds may be expected to carry the contamination away from the predicted direction by a distance proportional to the square of the distance from ground zero. The angular error due to this will therefore increase linearly with distance.

2.2 The higher activity of fall-out at shorter distances means

/that

that if the ship is off the central path of the fall-out the marginal activity is more likely to have a useful level of radiation.

2.3 The time of passage of the fall-out is roughly proportional to the distance of the point of observation. Since it is hoped to close-down one engine-room during the passage of fall-out, any reduction of this time will considerably ease the problem of endurance of engine-room personnel.

2.4 The characteristics of the fall-out are likely to vary with distance. By fitting an unmanned whaler with a duplicate set of instruments and stationing her close-in where there is likely to be a casualty-producting level of radiation, valuable information will be obtained. It has not been found possible, however, to fit the whaler with automatic water sampling equipment. It is therefore desirable that DIANA, who will be so fitted, shall be stationed close in to obtain radio-active sea-water samples which will be as representative as possible of those in an area of hazardous operational fall-out.

3. Safety Considerations

3.1 The other effects of the explosions (blast, heat, gamma and neutron radiations) will all be negligible hazards at distances down wind compared with the danger from fall-out.

3.2 The maximum permissible levels of external radiation for Operation MOSAIC have been laid down as follows (Joint Operational Plan Section E p.6, para. 2.2):-

/rep

	rep	r	When allowed	Remarks
Normal Working Rate	1.5	0.3	Once a week indefinitely	-
Lower Integrated Dose	15	3	Where necessary for the smooth running of the Operation.	No further exposure until average from beginning of Operation is down to N.W.R.
Higher Integrated Dose	50	10	Where necessary to recover vital records or information which might otherwise be lost.	As above.
Special Higher Integrated Dose	75	25	Applicable only in cases of extreme necessity and only to personnel who are not normally exposed to radiation.	No further exposure to radiation for three years.

(The dose above in roentgens is considered to be the maximum permissible dose contribution from hard radiation, to a total dose, including dose from beta radiation, expressed in 'roentgens equivalent physical').

5.3 The following table lists the probable early injurious effects on human beings (apart from genetic effects) to be expected from acute external doses of X or gamma rays over the whole body when received over a short period of time of the order of a day or less (U.S. Atomic Energy Commission quoted in 'The Protection of Workers Against Ionizing Radiations', International Labour Office, August 1955):-

/Acute Dose

Acute Dose (r)	Probable Effect
0-25	No significant effect ~~No obvious injury~~
25-50	Possible blood changes but no serious injury
50-100	Blood cell changes; some injury; no disability
100-200	Injury; possible disability
200-400	Injury and disability certain; death possible
400	Fatal to 50 per cent
600 or more	Fatal, probably to 100 per cent.

It will be seen from above that there appears to be no possibility of injury or even of blood changes after receipt of the ~~y~~ Special Higher Integrated Dose.

4. Most Probable Dose-Distance Relationship

4.1 A careful study spread over several months by E.M.L. Beale (A.R.L.) of all the data available to the Atomic Weapon Research Establishment including the results of both British and American tests has resulted in a graph showing the most probable distribution of activity with distance from MOSAIC explosions G1 and G2 (See Beale's MOSAIC report Ref. No. ARL/R1/C791). The latest information concerning the characteristics of the weapons likely to affect this distribution has been made available by A.W.R.E. for this purpose.

4.2 Representative figures taken from the graphs are:-

Distance (miles)	Total Dose to Infinite Time (roentgens) G1	G2
10	200	700
15	90	350
20	50	200
30	23.5	90
50	8.5	33
100	2.25	8.5
150	1.0	3.8

These figures have been derived assuming certain

/meteorological

meteorological conditions, namely a mean wind speed of 20 knots and an angular standard deviation for the distribution of the activity of 3 degrees. Furthermore it has been assumed that the cloud rises to 30,000 ft. for G1 and 40,000 for G2.

4.3 Some uncertainty is attached to these figures because of the large numbers of variables and the lack of sufficient experimental data, but Beale considers that if the best estimates available at the time, of the height to which the cloud will rise, the mean wind speed and the angular standard deviation are put into his basic formulae the results are unlikely to be out by a factor of more than 10, and that an error of a factor of more than 100 can be considered virtually impossible unless the bomb fails to explode.

5. Protection Afforded by the Ship

5.1 The dose figures quoted above (para. 4.2) assume that the dose is received from an infinite plane source of contamination. In practice the largest area from which radiation could possibly be received is the horizontal weather deck of the ship, since material falling on the surface of the sea will sink sufficiently for its radiation to be completely cut off. Experiments by A.R.L. (J.H. Williams) have shown that whereas an infinite area uniformly contaminated with cobalt 60 (1curie/sq. ft.) will produce a dose-rate of 368 r/hr at a position 3 ft. 6 ins. above the deck, the same density of activity on the deck of the frigate RAPID will produce a dose rate of only 190 r/hr. i.e. a reduction of 52%.

5.2 The A.R.L. experiments also showed that at the least protected of the covered positions for which measurements were made in RAPID, namely the Captain's Position on the enclosed bridge, the dose-rate was reduced to 40% of what it was on the weather deck. Thus the combined effect of a limited surface contaminated by fall-out and the physical shielding of the ship will produce a protection factor of approximately $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$. A similar figure of $\frac{1}{4}$ will apply to the slightly less penetrating radiation received from the fall-out deposited on the weather

/deck

deck of DIANA (which is comparable in area to that of RAPID).

5.3 By adequate pre-wetting of the ship's exposed surface followed by effective washdown, indications are that approximately 75% of the fall-out can be washed away i.e. a further protection factor of $\frac{1}{4}$ is effective.

5.4 Thus, for personnel under cover, at sea, in a ship which is being adequately pre-wetted and washed down, protection factors of approximately $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$ are applicable.

6. Stationing of H.M.S. DIANA

6.1 From a consideration of the above protection factors and the radiation tolerance doses discussed above, it has been decided that DIANA shall be at that distance from Ground Zero at which the hypothetical peak total dose in an infinite field would be 5 roentgens. The following will then apply -

Dose from an infinite field	5 r
Dose on deck	2.5 r
Dose below deck (no washdown)	$\simeq$ 1.25 r
Dose below deck (pre-wetting and washdown)	$\simeq$ 0.3 r

6.2 It should be noted that the dose to personnel below deck in an adequately pre-wetted and washed down ship is equal to the weekly dose at the Normal Working Rate.

6.3 It should also be noted that should, by an unfortunate mischance, Beale's curves be as much as 20 times too low, AND the pre-wetting and washdown procedures be inoperative, then the dose received by personnel just below the weather deck will be 20 x 1.25 r = 25 r which is no more than the Special Higher Integrated Dose.

6.5 The formula given by Beale relating

- x the distance in nautical miles from ground zero
- H the maximum height of the centre of the cloud above sea level in thousands of feet
- ū the speed of the mean wind to the centre of the cloud measured in knots

/and

and σ_θ the angular standard deviation (in degrees) of the distribution of activity on the ground (or sea)

for the hypothetical peak total dose of 5 roentgens in an infinite field is

$$x^{1.95} \quad 29015\, H^{-0.25}\, \bar{u}^{-0.05}\, \sigma_\theta^{-1}$$

6.6 It is seen that the dependence of x upon the mean wind $\bar{u}$ is very slight. Consultation with Mathewman suggests that a mean wind speed of 30 knots is most likely to be typical of conditions at the time of firing and this value for the mean wind has been adopted for the subsequent calculations.

6.7 Dependence of the distance x upon the height of the cloud H is rather more than the dependence of the distance upon the mean wind discussed above. The height of the cloud however is likely to tend to one of two values, depending on whether or not meteorological conditions favour water condensation in the cloud as it rises. If condensation occurs, then the latent heat given up will make the cloud more buoyant and it is likely to rise to the tropopause. If not, the cloud may remain many thousands of feet lower. For this reason two heights of cloud, with and without condensation, are considered for both G1 and G2.

6.8 The distance x at which a dose of 5 roentgens will be received is most sensitive to variations of σ_θ, the angular standard deviation. It is understood that this will be evaluated for the prevailing conditions before firing. The distance at which it is recommended DIANA be stationed can be found from the following table for both G1 and G2 according to the appropriate value of σ_θ and whether or not it is considered that the cloud will condense. (The heights of the cloud for G1 are taken to be 16,000 ft. (uncondensed) and 30,000 ft. (condensed) and for G2, 20,000 ft. (uncondensed) and 40,000 ft. (condensed)).

/TABLE

TABLE OF RECOMMENDED DISTANCES FROM GROUND ZERO
FOR DIANA IN NAUTICAL MILES

	G.1		G.2	
[illegible]	Dry Cloud	Condensed Cloud	Dry Cloud	Condensed Cloud
½	178	164	357	326
1	125	115	250	229
1½	101	94	203	186
2	88	81	175	160
2½	78	72	156	143
3	71	65	142	130
3½	66	61	131	120
4	61	57	123	112
4½	58	53	116	106
5	55	50	109	100
5½	52	48	104	95
6	50	46	100	91
6½	48	44	96	88
7	46	43	92	84
7½	44	41	89	81
8	43	40	86	79
8½	42	38	83	76
9	41	37	81	74
9½	39	36	79	72
10	38	35	77	70

Note: The figures given in the above table are, of necessity, based upon the best estimates of yield available at the time this paper was written (Mar 1956). It is probable that these estimates are not final and that, before firing day, A.W.R.E. representatives on the operation will be able to provide improved estimates of yield, which may require modifications to be made to the distances given above.

/7..

7. The Expected Duration of Fall-Out

7.1 This is difficult to estimate accurately but it is more sensitive to variations in the mean wind speed than is the estimated distance for observation previously discussed.

7.2 However the following figures for three values (two extreme and one mean) of σ_θ have been evaluated for G1 and G2 and refer to the time required for 95% of the fall-out to arrive.

Estimated Duration of Fall-Out

G1

σ_θ \ $\bar{u}$	10	20	30	40	50
½	1hr. 10min.	30min.	20min.	17min.	14min.
3	2hr. 40min.	1hr. 20min.	50min.	40min.	30min.
10	5hr.	2hr. 30min.	1hr. 40min.	1hr. 10min.	1hr.

G2

σ_θ \ $\bar{u}$	10	20	30	40	50
½	2hr. 20min.	1hr. 10min.	50min.	30min.	30min.
3	5hr. 30min.	2hr. 40min.	1hr. 50min.	1hr. 20min.	1hr. 10min.
10	9hr. 50min.	4hr. 50min.	3hr. 20min.	2hr. 30min.	2hr.

7.3 Until the correct values of σ_θ and $\bar{u}$ are available for conditions at the time of firing, for preliminary planning, values of 3 degrees for σ_θ and 30 knots for $\bar{u}$ may be taken as the most probable. In these cases we have

Most Probable Duration of Fall-out (95%) for G1 = 50 min.

Most Probable Duration of Fall-out (95%) for G2 = 1hr. 50 min.

7.4 These times are intended as a rough guide only. They may be in error by [redacted] a factor of two.

8. Recommended Procedure to Avoid Exceptionally Heavy Fall-out

8.1 Should, in spite of all precautions, DIANA find herself in an unacceptably high radiation field it is recommended that she steam at full speed in that direction at 45° to the bearing of Ground Zero which is most

nearly

nearly opposed to the surface wind.

9. Stationing of the Unmanned Scientific Whaler

9.1 The object of using the whaler is to obtain data as representative as possible of fall-out which would be capable of producing casualties aboard an unprepared ship caught in it under operational conditions.

9.2 The chief limitation on the closeness with which the whaler can be stationed appears to be an operational one, since it is essential that DIANA be on her own station in time to make all necessary preparations after having dropped the whaler. The exact location of the whaler is therefore left to the discretion of Mr. D.M.C. Thomas in consultation with ~~the~~ appropriate authorities at the time of the operation.

10. Conclusions and Recommendations

10.1 For accurate prediction of the best position at which to station DIANA it is essential to have last minute evaluation of $\bar{\sigma}$, the angular standard deviation in degrees of the expected distribtuion of the fall-out **at** sea level, of $\bar{u}$ the speed and direction of the mean wind to the centre of the cloud and of whether or not condensation is likely to occur in the cloud. From this data the recommended distance for the stationing of DIANA can be determined from the Table in paragraph 6.8. Distances are likely to be of the order of 65 miles for G1 and 130 miles for G2.

10.2 The bearing from ground zero will be determined by the direction of the mean wind.

10.3 The expected duration of fall-out can be determined from the Table in paragraph 7.2. Durations are likely to be of the order of 50 minutes for G1 and 1 hr. 50 mins. for G2.

10.4 The position of the dropping of the unmanned whaler is likely to be governed by the need for DIANA subsequently to reach her own station in time and is left for on-the-spot decision.

10.5 Subsequent to detonation it is desirable that the position of the radio-active fall-out at or near sea-level be tracked by

/survey

survey aircraft in order to keep DIANA informed so that she may be able if necessary to steam along an arc to the best position.

SECRET/GUARD

MESSAGE

Enclosure "A" to T.S.D.4480/55 dated 3rd January, 1956.

OUT

151246Z

From: Admiralty

15.12.55

To: C.in C. Mediterranean, Malta
C.in C. Home Fleet
C.in C. Far East Station

Info: C.in C. East Indies Station
F.O.F. Home
F.O.2 Mediterranean
Commodore Special Squadron
DIANA
DARING

W A R N I N G

NO UNCLASSIFIED REPLY OR REFERENCE IF D.T.G. IS QUOTED

GUARD

A.M.151245. Atomic Weapon Trial Montebello 1956 is only likely chance of testing protection of modern ships when passing through fall out of nuclear explosion.

2. Therefore considered essential to take this chance and DIANA, fitted with trunked air to boilers and other protective measures has been selected for this trial.

3. DIANA will be required on station 250 miles N.E. of Montebello about 2nd May and may be required in area till 30th June, 1956. She will be required to collect and observe fall out and try-out prewetting and closing down measures, and will be under operational control of Commodore, Special Squadron, in NARVIK.

151246Z

SECRET/GUARD

SECRET
GUARD

REFERENCE SHEET

From: Director Tactical, Ship Requirements & Staff Duties Division, Naval Staff, Admiralty, London, S.W.1.

Date: 15th February, 1956. Ref: T.S.D.4046/56

To: D.N.E. D.O.D. D.N.C.) 2 copies to each
D.P.R. E. in C.)
M.D.G. Superintendent A.R.L.)
D.O.R. A.W.R.E. (Att. Mr. Long))
Captain H.M.S. PHOENIX)
Commanding Officer, H.M.S. DIANA)

Copies to: V.C.N.S. D.C.(R. & D.) [illegible] S.L.
Controller A.C.N.S.(W)
D.C.N.S. A.C.N.S.

Operation MOSAIC - Observations and Trials by H.M.S. DIANA

[References:- (a) T.S.D.4480/55 dated 3rd January, 1956
(b) T.S.D.4035/56 dated 1st February, 1956]

A copy of the notes of a meeting held by D.T.S.D. in accordance with the above-mentioned references is attached. Any proposed amendments should be sent to D.T.S.D. by 1st March, 1956, otherwise concurrence will be assumed.

2. Attention of addressees is particularly invited to any noted "actions" for which they accepted responsibility at the meeting: it is requested that these may be pursued with the utmost vigour.

3. A copy of these notes and of all papers used at the meeting will be forwarded to the Commodore, Special Squadron for his information.

p. DIRECTOR TACTICAL, SHIP REQUIREMENTS & STAFF DUTIES DIVISION

SECRET
GUARD

NOTES OF A MEETING HELD BY D.T.S.D. ON 8th FEBRUARY, 1956

Operation MOSAIC - Observations and Trials by H.M.S. DIANA

The following attended and/or were represented:-

D.T.S.D. (Chairman)
E. in C.
D.P.R.
D.N.E.
D.N.C.
D.O.D.
M.D.G.
D.O.R.
Superintendent A.R.L.
Superintendent A.W.R.E.
Captain, H.M.S. PHOENIX
Commanding Officer, H.M.S. DIANA

1. The Chairman opened the meeting by explaining that this was the first opportunity for one of H.M. Ships to gain first-hand experience and to obtain information about fall-out and contamination. The purpose of the meeting was to consider all requirements, whether scientific, material or organisational, and to see how far these could be met and whether the ship's officers were satisfied with the arrangements being made.

ITEM 1

SCIENTIFIC TRIAL REQUIREMENTS

2. D.P.R. explained briefly the nature of the scientific trials which were aimed at determining the character of fall-out. Measurements would be made of its intensity at varying times after detonation and samples would be taken both from the air and the water around the ship. Besides the observations being made in DIANA, it was planned to have an un-manned

/whaler...

SECRET GUARD

-2-

whaler, at some position closer to ground zero, in which a second series of certain observations would be made [A.L. D.1219/56 dated 26/1/56 refers to the arrangements for providing this whaler]. It would be undesirable to drop this whaler in position before it was certain that a shot was to be fired.

3. The question of the distances from ground zero of DIANA and the whaler was then discussed and A.W.R.E. asked who would be responsible for DIANA's safety. The Chairman said that final responsibility would rest with the Commodore, Special Squadron (C.S.S.) but that Admiralty should give him some guidance as to what they would like achieved. [See Additional Note at end of these Notes]. It was tentatively suggested that the whaler might be 50 miles and DIANA some 200 miles from ground zero; A.W.R.E. stated that the expected dose to infinity at 200 miles from ground zero would not exceed 3R.

ACTION D.P.R. A.W.R.E.

4. It was finally agreed that D.P.R. and A.W.R.E. would produce an agreed recommendation concerning the stationing of DIANA and the whaler and that, subsequently, D.T.S.D. would arrange for this to be sent to C.S.S.

ACTION D[illegible]S.D.

5. DIANA questioned whether or not guns and boats should be uncovered (as in war) or covered (to ease any subsequent decontamination problem). After careful consideration of the importance of achieving realism while not leaving too tedious a post-operational task it was agreed that 50% should be covered and 50% uncovered.

ACTION DIANA

ITEM 2(a)

MATERIAL TRIALS

6. D.N.C. affirmed that he would have a considerable interest in the results of the scientific observations but that, otherwise, his main concern was to know whether action N.B.C.D. arrangements such as closing down, pre-wetting and the retention of mobility and the exercise of command proved satisfactory.

/7...

SECRET - GUARD

7. In this there might be some conflict with the scientific requirements since the water sampling could not be done at other than very slow speeds, while for pre-wetting a wind speed over the ship of about 20 knots was required. It is, however, believed that a normal wind speed in the area of about 15 knots may be encountered, but if the weather is calm then it was hoped that DIANA could be stopped periodically for short spells while the water samples were taken, the ship being pointed into such wind as there was the while. It was agreed that this was a decision for DIANA to make when the time came.

ACTION
D.P.R.
A.R.L.

8. D.N.C. further hoped that if the pre-arranged sampling methods failed for any reason that some stand-by arrangements would be provided, either by using a boat or by sampling water at the main inlets. D.P.R. agreed to provide for such an eventuality.

ACTION
D.O.D.
D.N.C.

9. D.N.C. proposed that trials of towing the special 30 ft. composite spar, which was being provided for obtaining water samples at each 6 ft. depth down to 30 ft., should be carried out from Portsmouth in the near future. D.O.D. agreed to arrange with C. in C. Portsmouth for this to be done by a ship stationed locally.

10. DIANA expressed some concern over the handling of this spar (weight 800 lbs.) but was reassured by D.N.C. that it was being made as light as possible and that suitable lifting and towing arrangements would be fitted into the ship.

/ITEM 2(b)

ITEM 2 (b)

ORGANISATION OF MACHINERY SPACES

11. E. in C. briefly introduced his paper on this matter (circulated with T.S.D. 4033/56 dated 1/2/56) and stressed particularly his desire to obtain answers to the questions posed in para.7(a) and (b) thereof. He stated, being supported here by D.N.C., that he would like the ship steamed with machinery space ventilation running so that we could find out precisely what contamination was drawn in, but we could not tell how serious a problem this contamination might produce. While there was no likelihood that such contamination would make the E.R. unworkable there might be some danger from the ingested hazard at some later stage. D.P.R. stated that his proposed air monitoring arrangements would determine the likely level of any hazard which might be ingested in the machinery spaces: DIANA drew attention to the ship's operational duties after Operation MOSAIC was completed and hoped nothing would occur to prevent his ship rejoining the Fleet by the planned date.

12. After some discussion, the Chairman stated that machinery space organisation should be such that no permanent ill effect on personnel resulted and that the ship should be fully operational by the time she had rejoined the Mediterranean Fleet. These provisos were accepted by all concerned.

ACTION
E. in C.
DIANA

13. E. in C. then drew attention to the possible thermal conditions in the machinery spaces, which might become so over-heated that ventilation must perforce be opened. To assist here, he was arranging to provide the ship with a limited number of ventilated suits and arrangements would be made for men working in these suits to be supplied with

/fresh...

fresh filtered air, via a portable double bottom blower.

14. A.W.R.E. stated that it was almost certain that fall-out would not start to arrive until after dark onboard DIANA; this might ease the problem of heat in closed-down spaces.

ITEM 3

A.B.C.D. ORGANISATION

15. PHOENIX briefly explained his paper on the organisational aspects which he wanted tried (circulated with T.S.D. 4033/56 dated 1/2/56) and emphasised his desire for approximate action conditions. D.P.R. thought that a service contamination meter placed high in the ship (para.6 of PHOENIX paper) would not produce an early warning of fall-out since expected levels would be far below what might have to be met in war; he stated that A.R.L. instruments onboard would provide the ship with the first early warning of fall-out.

16. DIANA was in agreement with PHOENIX proposals and stated that he hoped to carry out the following trials in his ship after and additional to the refit trials and before he left U.K.:-

(i) Closing Down Trial

(ii) Pre-Wetting Trial

(iii) Towing Trial of special A.R.L. spar

(iv) Steaming Trial in accordance with E. in C. requirements.

ACTION DIANA — He thought these trials would require four days (plus possibly 2 spare) and he would include them in his proposed programme to C. in C. Plymouth; they would probably start soon after 15th March, 1956.

/ITEM 4

ITEM 4

U.S. NAVAL EXPERIENCE OF FALL-OUT

17. The meeting took note of the paper (circulated with T.S.D. 4480/55 dated 3/1/56) giving an account of the experiences of U.S.S. PHILIP in fall-out.

18. The importance of indoctrinating DIANA personnel in radiation exposure tolerances so as to eliminate ill-informed and unfounded anxieties was discussed, and M.D.G. agreed to arrange for the ship's Medical Officer (designate) to be fully instructed before he joins. In this connection also, D.T.S.D. undertook to arrange for DIANA to receive a copy of the Medical section of the second report of the Hydrogen Bomb Working Party [A.L. M/TSD.303/54 dated 12/12/55 Appendix "G", classified "Confidential" but not "Atomic"]

ON
G.

ON
S.D.

ITEM 5

RADIAC INSTRUMENTS AND PROTECTIVE EQUIPMENT

19. D.N.E. hoped that he would be able to supply DIANA with a full outfit of operational radiac instruments. It was, however, pointed out that the individual flash dosimeters provided would constitute only an "administrative exercise" since it was not expected that the small dosages encountered at long distance from ground zero would register on these dosimeters. A small number would, however, be "dosed up" beforehand so as to give some reality to the exercise. PHOENIX suggested that a larger number of Quartz-Fibre Dosimeters (0-5R) should be provided and D.N.E. agreed to see whether this could be done.

ION
.E.

20. A.W.R.E. offered to allocate up to 150 film badges for use onboard DIANA, to be supplied from NARVIK at Monte Bello. Although these are not contemplated as war-time naval issue it was agreed that, in this special instance, they would be welcome. If returned to NARVIK after the operation A.W.R.E. would develop the badges and record any doses received.

TION
.R.E.
NA

/21...

21. DIANA queried the robustness of radiac equipment because he wished to fire his guns on passage. He was informed that all service radiac equipment, provided it was in a proper stowage, should be unaffected. A.R.L., however, expressed great concern over the gun-firing proposal as much of his scientific equipment would be laboratory material, (since time had not allowed of other being obtained) and this was delicate and would not appreciate gun-shock. D.N.C. agreed to investigate the provision of shock-proof mountings for the A.R.L. equipment, but it was emphasised by the Chairman that, sympathetic though he was towards the ship's gunnery proficiency, the successful working of the trial equipment in Operation MOSAIC was of higher priority on this occasion.

ACTION D.N.C.

22. D.N.E. stated that he was doubtful whether he could obtain any of the newest form of experimental protective clothing in time but he would do his best; in any case he would arrange for certain supplies of the earlier experimental pattern, but the ship should take a full war outfit of normal protective clothing. It was also agreed that DIANA should take a 50% outfit of skeleton survivors kit for issue to monitoring and decontamination teams as found necessary.

ACTION D.N.E.

ACTION DIANA

23. DIANA referred to difficulties of getting unauthorised stocks of special equipment because the nature of the operation could not be made fully known to Dockyard Departments at Devonport. D.T.S.D. thought that A.M.151245/Dec. could be used as authority but D.N.E. agreed to contact the Command Supply Officer and ask him to smooth the way for any special demands.

ACTION D.N.E.

24. PHOENIX agreed to lend DIANA a number of radiac sources for use in working up and training on passage.

ACTION PHOENIX

25. PHOENIX agreed to transfer two experimental plastic fire main hoses to DIANA for trial during the operation.

ACTION PHOENIX

/ITEM 6

ITEM 6

ANY OTHER BUSINESS

26. In view of the importance of keeping the experimental gear in good order and repair, and the lack of base facilities during the operation, DIANA asked whether an electric welding plant could be made available. D.N.C., who was not whole-heartedly in support, agreed to investigate.

ACTION
D.N.C.

27. DIANA enquired what electrical power supplies would be needed for the A.R.L. equipment and was told 230 volts A.C. at 60 cycles; this, DIANA stated, could be arranged.

ACTION
DIANA

28. DIANA pointed out that he could provide accommodation for the Medical Officer, E. in C.'s representative and 2 A.R.L. representatives - but no more, unless hard-lying was acceptable. D.T.S.D. agreed to make this fact clear to N.A.2 S.L.

ACTION
D.T.S.D.

29; A.W.R.E. enquired who, in DIANA, would act as Health Physics Officer; it was agreed that Mr. Thomas, A.R.L. representative, who would make the passage out and back in DIANA, should undertake this duty.

30. D.P.R. and A.R.L. were informed by DIANA that, after the operation, the ship would return no nearer to U.K. than Malta. D.P.R. agreed to pursue arrangements for bringing all trial equipment and equipment on loan to U.K. from Malta. DIANA would, as soon as it could be foretold, report his date of return to Malta.

ACTION
D.P.R.

ACTION
DIANA

31. DIANA agreed to render full reports on all aspects of the trial. These should be forwarded through Administrative Authority but advance copies to D.T.S.D., D.P.R., D.N.E., D.N.C. and E. in C. would be very welcome.

ACTION
DIANA

/32.

32. A.R.L. stated that it would be necessary for DIANA to call in at Onslow between shots, so that A.R.L. samples etc. could be flown to U.K. This requirement was noted for later arrangement between DIANA and C.S.S.

ACTION
DIANA

ADDITIONAL NOTE

33. From time to time during the meeting the question arose of responsibility for ensuring that, while DIANA maintained a station suitable for receiving fall-out so that the various trials could proceed, she was not subjected to any unsafe hazard through radiation effects.

34. By the terms of the directive for the conduct of Operation MOSAIC, DIANA will come under the orders of the Commodore, Special Squadron, who is responsible for the "execution (including Safety and Security) of the operation as a whole....."

35. The Chairman said that he would arrange for a copy of the notes of the meeting to be forwarded to C.S.S. for his information and he had no doubt that C.S.S. would be able to discuss details with DIANA when that ship joined his squadron.

ACTION
D.T.S.D.

36. A.W.R.E. pointed out that, once the actual operation was under way, C.S.S. and his communications would be heavily involved with aircraft and scientific signal traffic and that DIANA would, to some extent, be out on his own. It was, therefore suggested that a prior visit by Commanding Officer (designate) DIANA to A.W.R.E., where more detailed safety indoctrination could be given, would be of value. Both the Chairman and DIANA welcomed this suggestion and it was agreed that A.W.R.E. and DIANA should make the necessary arrangements.

ACTION
A.W.R.E.
DIANA

/37...

37. A.W.R.E. stated that Mr. Long of A.W.R.E. (Trials Manager for Operation MOSAIC) would be flying to Monte Bello on 4th March, 1956. Mr. Long (A.W.R.E.) agreed to contact D.T.S.D. shortly before this date in case it was desired to send any special information re DIANA to C.S.S.

ACTION
A.W.R.E.
D.T.S.D.

38. D.T.S.D. will endeavour to arrange for a copy of the "Introduction" to the Joint Operational Plan for Operation MOSAIC to be sent to Commanding Officer, H.M.S. DIANA before the ship leaves U.K.

ACTION
~~DIANA~~
D.T.S.D.

[redacted]

John Pollard 23/6/83

1084/2

Record of Commodore Special Squadron

Subject

Radiation Hazard in Diana

OFFICE COPY

SECRET

RADIATION H[illegible] AND PRECAUTIONS [illegible] H.M.[illegible] D[illegible]

(The Scientific Superintendent's Letter of 4th May, 1956)

II

No. 1074/2
The Scientific Superintendent,
H.M.S. [illegible]

Thank you very much for this excellent report. I would be grateful if the special clothing, filters and equipment specified could be loaned to H.M.S. [illegible].

2. I fully understand your comments on the question of responsibilities.

H. G. MARTELL

H.M.S. NARVIK,
at Monte Bello
8th May, 1956

COMMODORE
SPECIAL SQUADRON

SECRET   Commodore.

FROM : SCIENTIFIC SUPERINTENDENT

DATE : 4th May, 1956

TO : COMMODORE, SPECIAL SQUADRON

RADIATION HAZARD PRECAUTIONS IN H.M.S. DIANA

As we arranged, Mr. Hole visited H.M.S. DIANA yesterday (3rd May) and inspected all the precautions which have been arranged and discussed there with the officers concerned. I attach a copy of the report he submitted to me after this visit.

I endorse all the comments he makes, and am prepared to release the special clothing, filters, and equipment if you feel that DIANA should make use of them. I must emphasise, however, that in making his comments Mr. Hole is only expressing his own opinion as an expert in this field, and the offer to lend equipment and clothing is being made to assist DIANA carry out this exercise. We can not, however, assume any direct responsibility for the Radiological Safety of DIANA since this lies outside our terms of reference.

P. Maddock

4/5/56

COMMODORE
SPECIAL SQUADRON
MAY 1956
1058H/2

SECRET

COMMENTS ON A VISIT TO H.M.S. DIANA TO DISCUSS PROTECTIVE MEASURES

During my visit to H.M.S. DIANA today I was able to see and discuss the proposed radiation protective measures they are to take.

Originally it was intended to have the ship "shut down" all the time during fall-out but recent information on the length of time they may be in the "fall-out" zone makes it impossible to do this.

In order to "open up" certain personnel have to leave the Citadel, go out in the open for a few minutes and return to cover.

This operation can be carried out quite safely using the protective clothing and hoods they have on ship.

Complete protection of the personnel in the engine rooms is more difficult to arrange since it is difficult to assess the hazard involved. Whilst accepting that this is one of the problems which is being examined in this exercise, I feel that until more is known about the hazards, they should play safe.

The protective clothing they propose to use in these boiler rooms are of two types:-

(i) A plastic suit similar to the Windscale Alpha Suit which completely encloses the body and has it's own air line. This type of suit tends to tear and the casualty rate in engine rooms of this type of suit is high.

(ii) A closely woven fabric suit similar to the Hurricane suit. They have no hoods for this clothing and have been using an ordinary flash hood + respirator + anti-gas hood as a substitute. None of these fit to the suits and it leaves the neck region exposed. It is heavy and most uncomfortable to wear.

The air supply to the engine rooms is ducted, and has to make several changes in direction including one of 180° before it is discharged into the room. This will probably lessen the carry-through of R/A material by impaction, with a corresponding build-up at the bends.

I suggest that their problem in protective clothing is one of physical hardship rather than the radiation hazard. In this respect their present clothing is unsuitable and I would suggest with your agreement that we offer them twenty R/A suits + undervests from our present stock.

This will not jeopardise our stock position for G.1 but might leave us short for G.2. It should be a simple matter to signal for replacement from U.K. since it is intended that the Buffalo stock will be built up from our used suits here.

The filters in their respirators are service type which are heavy and not too efficient for R/A materials. Our filter type D/3/45 will fit into the standard face piece and are specially designed for this work.

We have adequate stocks to supply them with twenty five.

They are deficient in one or two other items which we can supply.

(i) Dose rate meters reading above 200 r/hour. We can supply the [illegible] type now that our main stock has been received.
(ii) Headphone to [illegible] Contamination Meter. We can supply as this type is also used in the 1920 monitor.

The clothing they will be using for decontamination and hosing down is adequate.

My general impression was that everyone understood the basic problems and how to tackle them, but that they have fallen short in the apparatus and tools to do the job.

DEFE 16/595

BR/35/1

UK/UNCLASSIFIED

HMS DIANA

25th November.

at Sea.

Dear Andy,

Thanks for your letter, your remarks have been passed on and everyone sends their best regards. As regards your questions – you are under the mistaken impression that we have special pumping arrangements. This is not so, we used the normal pumps and primers as fitted in all this class. All we carried as extras were hose lengths (ordinary N.S.) – breeching pieces – normal except for pressure gauge connections, – jet/spray nozzles (N.S.) and brackets made up for the job, absolutely nothing different from 'off the shelf'. The particular hose you mentioned was put on board, I think by 'Phoenix' we have no particulars and I believe they are evaluating it for all purposes. I have not bothered to include design of our quadrant (or bracket) as they ain't really good enough, anyone could do better! Afraid the reply is negative but factual.

It will be some time before you get this as we are at sea and it will have to go from Aden. True to our usual form we are engaged in the current manoeuvre but from the wrong end – frankly its a better end but Aden is the [illegible]

[illegible] limitations; nevertheless everyone is surprisingly cheerful. We've had our moments & ?? the gunnery jacks have fixed their pieces and even my stuff is working better than when you knew it. Water is even quite plentiful! The encouragement from your folks is most cheering to hear amid all the moaning & groaning elsewhere, it takes some sorting out yet. Meanwhile we won't be loathe to go round the Cape with a few interesting stop overs.

How you do flog your countrymen, don't you ever live a normal life?

Must catch the mail now, best wishes from us all

Yours sincerely

Mike Wilson

UK/[redacted]CLASSIFIED

PS. [illegible] is writing to thank you for the [illegible]

John Pilger
4/7/83 [redacted]

SECRET

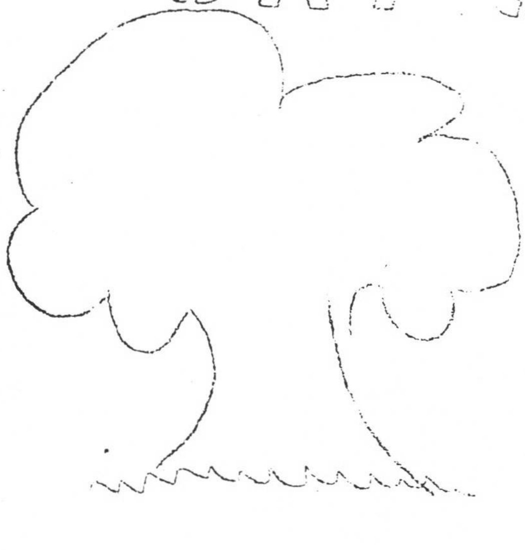
~~U.K. EYES ONLY~~

[redacted]

E
365

ADM 296/3

HMS DIANA'S REPORT ON



OPERATION MOSAIC

SECRET

~~U.K. EYES ONLY~~

PRO

CONFIDENTIAL

REFERENCE SHEET

In reply please quote:-
M.605/40/56

ADMIRALTY

From: Head of Military Branch

Dated: 30 October, 1956.

To: D.T.S.D.
D.P.R.
D.N.E.
D.N.C.
E. in C.
M.D.G.
Captain H.C. Martell

Copy to: D.D.N.I.(S)

Operation MOSAIC

H.M.S. DIANA's Report

Following a study of H.M.S. DIANA's report on Operation MOSAIC it was suggested that the information contained therein did not warrant the retention of the marking "U.K. EYES ONLY". D.N.I., who has been consulted, agrees. It is requested, therefore, that the words be removed from the copy/ies held by you. Head of M's reference sheet of 30th July, 1956, (M.605/40/56 (not to D.N.I. or Captain Martell)) refers.

2. D.P.R. is requested to communicate this information to the holders of the report at A.R.L.

for Head of Military Branch.

CONFIDENTIAL

NFIDENTIAL

H.M.S. DIANA,
at ADEN.

5th August, 1956.

No. 01/29
SECRETARY OF THE ADMIRALTY
DIRECTOR,
ADMIRALTY RESEARCH LABORATORY,
TEDDINGTON
COMMANDING OFFICERS,
H.M.SHIPS PHOENIX, NARVIK.

H.M.S. DIANA - REPORT ON OPERATION MOSAIC

It is requested that the following amendments may be made to H.M.S. DIANA's report on Operation Mosaic :-

Section II - A.B.C.D. - C (i)2 Line 6 - For 'personal' read 'personnel' ✓

Section IV - ENGINEERING - B (iii) line 1 for 'Naval Store' read 'Victualling Store.' ✓
D5 line 5 for 'after' read 'forward' ✓
E(i) After 'No.1 diesel generator add 'Turbine turning motor' ✓
E(iii)4 delete all after '$15\frac{1}{2}$ knots' ✓
E(iii)6 line 1 for 'ship's tanks' read 'Reserve Feed Tanks' ✓

SECTION V - ELECTRICAL - (vi)(d) line 10 after 'Control outfit' add 'K.H.C.' ✓

SECTION VII - NUCLEONIC INSTRUMENTS - Appendix A - after 'Dosimeter Q.F. No.3 add ✓

11091	Dosimeter	Q.F. No. 4	10	Nil
"	"	Q.F. No. 5	3	Nil

SECTION VIII - THE ARMAMENT - B(iii)(c) line 2 for 'intended' read 'internal' ✓
B(vii) last line delete '(Photograph see Appendix D) ✓
Appendix B table 1 for 'Right-training under' read 'Right trunnion under' ✓
Table III immediately above table insert
HOTSHOT at H+10
FLASHLIGHT at H+12 ✓

E(iv) line 2 for 'touched' read 'untouched' ✓

IDENTIAL

C A P T A I N

Distribution	Copy No.
Admiralty -	1 - 13
A.R.L. Teddington	16 - 18
H.M.S. PHOENIX	14
H.M.S. NARVIK	15

Copy No. 15

H.M.S. [illegible]'s REPORT ON OPERATION MOSAIC

C O N T E N T S

Section I — NAVIGATION

A. HOTSHOT
B. FLASHLIGHT

Section II — A.B.C.D.

A. HOTSHOT
B. FLASHLIGHT
C. Organisation

Section III — PRE-WETTING

A. Operational Appreciation
B. Efficiency
C. Organisation

Section IV — ENGINEERING

A. Introduction
B. Protective Suits
C. Final Organisation
D. Machinery Space Ventilation
E. Machinery Operation
F. Radiological trials, Monitoring and Decontamination
G. Personnel

Section V — ELECTRICAL

Section VI — HABITABILITY

Section VII — RADIAC INSTRUMENTS

Section VIII — THE ARMAMENT

A. General
B. Gunnery
C. Fighting Efficiency in State 1A
D. Radar Tracking of Fall Out
E. Torpedo and Anti-Submarine

Section IX — TRAINING

Section X — COMMUNICATIONS

COPY NO. 15

SECTION I: - NAVIGATION

A - HOTSHOT (All Times Hotel)

I weighed at 0400 on 16th May and proceeded from the Parting Pool to lower the specially equipped whaler in position 20° 18.2' S, 115° 32.3' E. This was 356° 4.9' from Ground Zero.

2. Both these positions, together with the ship's track from 1326 until 2100 on 16th May are shown on a tracing attached as Appendix A.

3. The whaler was anchored in 25 fathoms and at 0630 course was set at 14 knots for position 024 Ground Zero 51 miles - D2 on the tracing. (Position D1 was cancelled before the whaler was anchored).

4. A new position - D3 on the tracing - 002° 40 Miles from Ground Zero was ordered by C.T.F. 308 and at 0840 I altered course to 305° to comply.

5. At H. Hour, 1200, I was three miles east of this position and course and speed were adjusted so as to pass through it at 1325, the E.T.A. of the fall out, and steering 180° at 10 knots. This gave a relative wind speed of 13 to 15 knots.

6. Fall out arrived as expected but stopped after twenty minutes. This fact, together with the observed path of the cloud after H hour, was interpreted as meaning that I had only cut across a small sector of the leading edge of fall out, and that the main area lay to the E.N.E.

7. I therefore altered course to 070 at 1335, informing C.T.F. 308 of my actions. At 1439 course was altered to 020, and later 010 and speed increased to 13 knots, to comply with further instructions from C.T.F. 308. The new position ordered was reached at 1615 but without detecting any fall out, so course was altered to 100° at 1625 and 140° at 1705. This was reported to C.T.F. 308 who then ordered me to steer 090°.

8. A small patch of active water was found at 1808 and at 1910 more considerable activity in the water was discovered. It had stopped by 1935 and so course was reversed to 270°.

9. However no greater activity was detected and at 2005 I altered course to 214°, the bearing of Ground Zero. At this stage, H + 8 hours, it was felt that no further value was to be gained by searching.

10. Fall out ceased at 2100.

11. Course and speed were adjusted to reach the whaler at 0600, first light, and, after the scientific equipment had been recovered, it was sunk by ramming.

12. I then returned to the Parting Pool.

Copy No. 15

H.M.S. DIANA's REPORT ON OPERATION MOSAIC

SECTION I: - NAVIGATION

B. - FLASHLIGHT (All Times Hotel)

I weighed at 0415 on 19th June and proceeded from the Parting Pool, increasing speed to 20 knots as soon as it was prudent.

2. A Dan Buoy, specially fitted with scientific equipment, was laid in 20 fathoms, in position 20° 21' S, 115° 26' E. This was 303° 7 miles from Ground Zero. The whaler earmarked for this trial overturned and sank during the false alarm the previous day.

3. A tracing showing both positions together with the ship's track from 1100 on 19th until 0020 on the 20th is attached as Appendix B.

4. The laying was completed by 0553 and course was set at 25 knots for position 050 Ground Zero 100 miles - marked as 1 on the tracing.

5. At 0700 a balloon was released for wind finding. As it only rose at about 600 feet per minute it was not until 0920 that the results were reported to C.T.F. 308.

6. At 0714 I was ordered by C.T.F. 308 to proceed to Position 2 on the tracing, a further 49 miles from Ground Zero. Part of the signal ordering this change required verification and at 0826 course was adjusted to 065°.

7. A second wind finding balloon was released at 0946 and the results reported to C.T.F. 308 at 1054. The track chart of this second run is attached as Appendix C.

8. At the time of firing I was 97 miles from Ground Zero. On the information so far available, fall out was expected to arrive at 1405 and to last for two hours. It was therefore intended to be ready in all respects by 1330, and at 1215 the Engine Room were told to prepare to disconnect the port shaft.

9. However, at 1220 C.T.F. 308 ordered me to take up a new station - Position 3 on the tracing - six miles south west of my position at that time. The E.T.A. of the fall out was stated to be 1230 - 1300.

10. I continued on the same course - 065° - while the ship was being closed down and the port shaft disconnected. At 1238 course was altered to 085, to obtain efficient prewetting, and at 1257 to 225, when the ship was fully closed down and ready to receive fall out.

11. This was first detected at 1326 and course was altered to 095 and later 105°, with a 20° weave superimposed, so that a relative wind of about 20 knots was obtained varying in direction from Red 20 to Green 20. As the ship was only making about 2 knots through the water, each leg of the weave took four to five minutes.

12. As the activity continued to be very slight, instructions were requested from C.T.F. 308 at 1515. At 1556 course was altered to 330 and speed increased to 10 knots, as it was thought that the main fall out probably lay to the North.

13. At 1715 instructions were received from C.T.F. 308 to steer 000° at 25 knots for 2 hours and then 046°. Course was altered and speed increased to 18 knots, this being reported to C.T.F. 308. Course was altered to 020° at 1755 in order to cut the corner.

Copy No. 15

SECTION I: - NAVIGATION

B. - FLASHLIGHT (Continued)

14. Course was altered to 046 at 1948 and maintained until 2135 although there was no activity and it appeared likely that we were astern of the fall out and not capable of catching up with it.

15. At 2135 course was reversed to 227 to steer for the Dan Buoy. By 0020 the ship was steaming on two shafts, the canvas gear had been ditched and with the O.O.W. now on the Bridge I proceeded at economical speed to the position of the Dan Buoy.

16. This was sighted at 1025 on the 20th and after the scientific equipment had been recovered by whaler, it was sunk by small arms fire at 1055.

17. The whaler was hoisted and course set for the Parting Pool.

Conclusions

18. It was a very great advantage being able to anchor the whaler and dan buoy. On none of the four occasions on which the evolution was carried out, did either the whaler or dan buoy drag. However, the lowering of a whaler in darkness without slipping gear, rigging a radar mast and then anchoring it was no easy task, except in ideal conditions. Slipping gear could not be used as the fore-and-after chain would have dropped onto the delicate scientific instruments attached to the thwarts. In view of these difficulties, it is recommended that, for any future operation of this nature, lines or circles of dan buoys, or inflatable life-saving appliances, be used.

19. Conning and controlling the ship from the Operations Room, for the periods of twelve to fourteen hours which were required, presented no difficulty, although the fitting of a Rudder Indicator is considered to be an important addition. This has already been proposed by H.M.S. DECOY, and forwarded by the Flag Officer, Flotillas, Home Fleet to Commander-in-Chief, Home Fleet under cover of his letter No. Flo.206/5 dated 15th May, 1956.

20. The Operations Room was manned by two officers, one R.P. rating, and one of the T.I.U. crew acting as communication number with A.B.C.D. H.Q. Another R.P. rating was on watch in the 293 office and all worked thirty minute tricks. A similar arrangement was used for the Wheelhouse Crew.

21. Records of temperatures and humidities in the Operations Room are given in Section VI .

SECRET

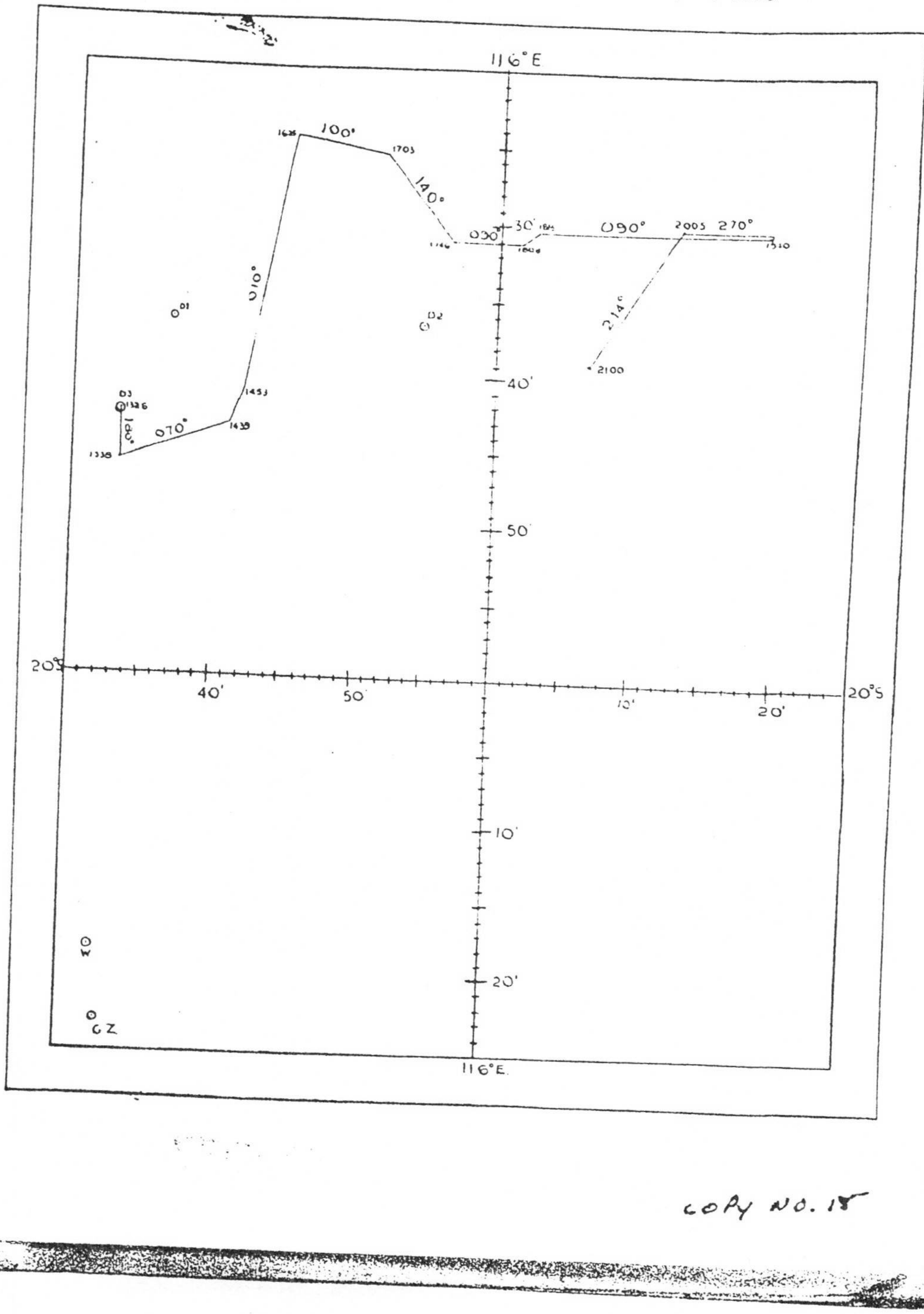
H.M.S. DIANA's REPORT ON OPERATION MOSAIC

APPENDIX A TO SECTION I

H.M.S DIANA

Track Chart

From 1326H. May 16th to 2100H May 16th 1956



COPY NO. 15

APPENDIX B TO SECTION I

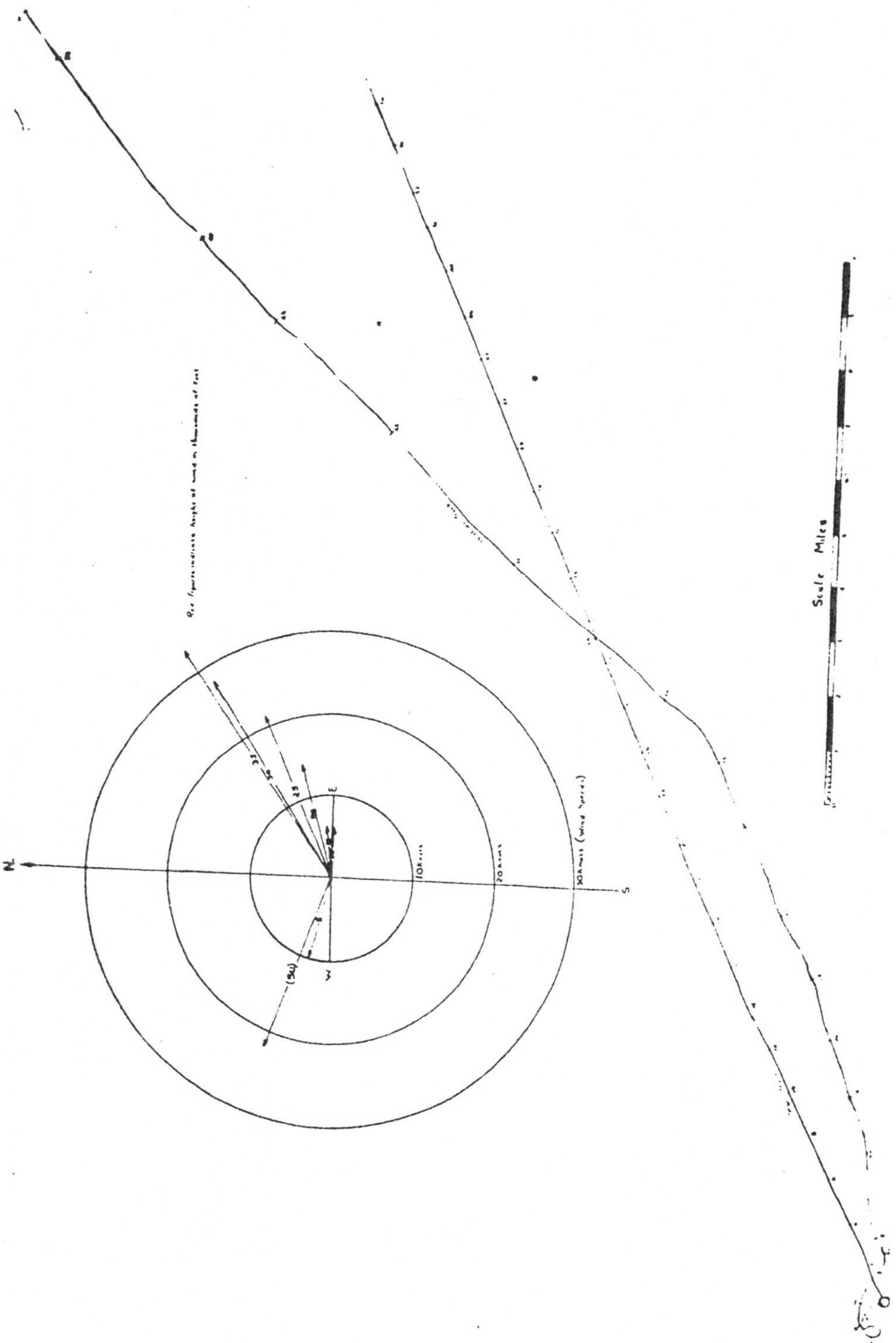
HMS DIANA

Track Chart

From 1100H June 19th to 0020H June 20th 1956

Copy No. 15

APPENDIX C TO SECTION I



COPY

H.M.S. DIANA's REPORT ON OPERATION MOSAIC

SECTION II - A.B.C.D.

A - Narrative HOTSHOT

The device was seen to explode at 1151 on Wednesday, 16th May, 1956. The Ship's Company was sent to Action Stations at 1220 and the Ship was fully closed down in A.B.C.D. State 1A by 1235. The E.T.A. of the 95% zone of the fall-out was 1325, but in fact, instruments in the Scientific Centre detected faint traces of fall-out at 1305. The Ship's Company went to Shelter Stations at 1301, and pre-wetting was started at 1304.

2. Manometer readings in the Citadel were recorded as follows:-

Forward Citadel	...	$2\frac{1}{2}$" pressure
After Citadel	...	$2\frac{1}{2}$" pressure

These pressures were achieved 6 minutes after the Citadels had been closed down and were maintained throughout the operation, a period of 13 hours.

3. At 1330 the ship had reached the expected fall-out area. Internal monitoring parties were sent out but no recordings were noted on the instruments. After some time it became apparent from scientific observations that the Ship was not in fact in the middle of the fall-out area but was on the fringe of the radioactive cloud. It was not until 1915 that radioactivity began to build up and at 1920 Internal Monitoring Parties commenced to pass readings. Readings varied from 0.1 MR to 3 MR in the forward Citadel but only in positions under decks which were not fully pre-wetted. In the after Citadel readings varied from 0.1 MR to 0.8 MR under pre-wetted surfaces. There was at no time any airborne radioactivity in either citadel nor were there any readings shown on the personal dosimeters of those officers and ratings wearing them at Shelter Stations or at any position within the Citadels.

4. Fall-out ceased at 2100 and at 2135, Monitors fully equipped in protective clothing, proceeded out of the Citadels, turned off the pre-wetting and commenced passing readings. The overall level of contamination on the Upper Deck was of the order of 5 MR with one or two patches of 10 MR and one area on the Quarter Deck which gave a reading of 40 MR. This high reading on the Quarter Deck was due to a faulty pre-wetting connection which had bown out during the operation, leaving this area of deck not pre-wetted.

5. Decontamination parties commenced operations at 2230. They used hoses and scrubbers which had previously been stowed inside the Citadels. It was found that decontamination in the dark hours was a fairly long proceeding; however by 0110 on 17th May the Upper Deck was declared by the Senior Scientific Officer to be safe for use. The readings were by now down to 0.1 MR. Special parties in protective clothing went out and removed all the special canvas covers, these were lowered over the side as they were to some extent radioactive.

/6. As no anti-gas . . .

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC

SECTION II - A.B.C.D. (Contd.)

6. As no anti-gas Pavement was carried in the ship at the time of the first event, canvas strips were laid along the port side of the upper deck between the Access doors of the Forward and After Citadels, to lessen the risk of contamination being carried into the Citadels. This was only partially successful despite the fact that boots and shoes were removed at the Citadel doors and, as a result a signal was sent to Admiralty asking for a supply of white overshoes before the second event was due. These were received and made a great difference. Anti-gas Pavement was also obtained in Singapore before the second event at the suggestion of Lieutenant ANDREWS, R.A.N, the A.C.N.B. A.B.C.D. observer during the trials.

/B - Narrative FLASHLIGHT ...

Copy No..15..

SECTION II - A.B.C.D. (Contd.)

B - Narrative FLASHLIGHT

The flash ffom the device was observed fine on the starboard quarter at 1014 on Tuesday 19th June, the Ship being 97 miles from the tower. The Ship's Company went to dinner at 1130 and to Action Stations at 1222, the Ship having received a signal from C.T.F. 308 saying that fall-out could be expected at 1230.

2. Shelter Stations was ordered at 1232 and the Citadels were closed down and pressurized by 1245. Good pressures were recorded in both Citadels within 4 minutes of closing down and pressures were maintained throughout the closed down period as follows:-

Forward Citadel	...	$1\frac{3}{4}$"
After Citadel	...	$2\frac{1}{8}$"

3. At 1325, the Scientific Centre reported the first traces of fall-out and orders were passed from A.B.C.D. Headquarters for inside monitoring parties to start monitoring. At 1345 the forward inside monitoring party reported readings of 0.5 MR on the forward messdeck under the non-prewetted area of the forecastle and a similar reading was reported by the After Party in the C.P.O's bathroom at 1350. This bathroom is under "Y" Gundeck which was not quite so well pre-wetted as the remainder of the Upper Deck.

4. At 1440 the readings forward were in excess of 10MR. Those positions maintained these readings until 1845 when readings dropped to 0.4 MR. No readings were recorded on personal dosimeters.

5. It was apparent that the ship was out of the fall-out area; however orders were received to try and track the cloud until 2130. No further fall-out was detected and outside Monitoring Parties were ordered out at 2147 to turn off pre-wetting and commence monitoring. Upper Deck readings varied but in the main were below 10 MR, with the exception of the starboard side of the Quarterdeck, a small area of B Gundeck and an area starboard side abreast the forward tubes which gave off scale readings.

6. At 2245 the first Decontamination Parties went out and commenced work. Once again decontamination was hampered by darkness but with previous experience fresh in their minds, the parties worked very much more smoothly than on the previous occasion. Once the decontamination was well under way, canvas gear parties, dressed in protective clothing, removed the special canvas gear covering the bridge, carley floats, reels, flotanets, etc., and disposed of these covers over the side. All covers were giving readings in excess of 10 MR.

7. By 0020/20 June contamination readings on the Upper Deck had dropped sufficiently low to enable the Citadels to be opened up. Some areas however, were declared by the Scientific Staff to be giving unacceptably high counts. These areas comprised the Iron Deck starboard side abreast forward tubes, starboard side of the Quarterdeck and M1 STAAG mounting. These positions were roped off for a period of up to 20 hours until after repeated decontamination they were declared safe to use.

8. The Ship secured from Shelter Stations at 0025/20th June and Anti-Gas pavement was laid along the upper deck between the two Citadels. This pavement coupled with the use of the Overshoes prevented contamination from getting inside the Citadels. Overshoes were worn for 24 hours after the completion of the exercise.

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SECTION II - A.B.C.D. (Contd.)

C - Organisation

(i) Undressing Stations

As an ad hoc arrangement, the work carried out in accordance with the addendum to D.N.C's letter No. 11/878/55 dated 21st December, 1955 (copy attached as Appendix "A") was reasonably satisfactory. Two defects, however, had to be remedied as a result of experience gained from the first explosion, i.e.,

(a) Singapore Dockyard was asked to modify the drainage from M1 and M2 STAAG deck, as pre-wetting water, much of it radioactive, was overflowing from this deck down on to the forward undressing station.

(b) The beef screen situated in one corner of this undressing station materially obstructed the work of the undressing station. This was landed for the remainder of the trials and it is strongly recommended that it is landed permanently as it renders the forward undressing station totally inoperative.

2. One of the main lessons learnt from these trials was the imperative need for properly built-in undressing stations, clear of obstructions and leakages from the deck above. The arrangement by which they are constructed by temporarily enclosing an area outside the cleansing station with a canvas curtain is not satisfactory. The wind blows the curtains aside and brings in radioactive spray on ~~personal~~ personnel being undressed, and in cold climates particularly this exposure would not be acceptable. If reasons of space and topweight make a permanently fitted undressing station impracticable, or as an interim measure, it is suggested that an area of deck adjacent to cleansing stations be fitted up so that it could be enclosed with steel shutters on the roller blind principle, which could be rolled back when not in use. (With a space for a canvas door).

(ii) Cleansing Stations

Both cleansing stations were equipped with a contamination meter Mark I (Power Operated) and no difficulties were experienced in operating these instruments, except that lack of space to rig up proper shielding did make personnel monitoring a little inaccurate as background built up.

2. Apart from this, the space in the after cleansing station (After Ship's Company Bathroom) proved quite adequate for cleansing purposes. This was not the case in the forward cleansing station.

3. The Forward Petty Officers' Bathroom is designated as the Forward Cleansing Station in the "Daring" Class, but it was far too small for the purpose, particularly as it had to be used as the main cleansing station. The reasons for this, which would apply to a greater or lesser extent in wartime, were:-

/(a) In this . . .

Copy No. 15

SECTION II - A.B.C.D. (Contd.)

(a) In this trial, at any rate, it was necessary to control all engine room watchkeeping from the forward Citadel.

(b) Approximately two thirds of the Ship's Company are accommodated forward and thus by far the larger number of men who formed the various decontamination and canvas disposal parties re-entered the forward citadel.

(c) The Scientific Centre was in the forward Citadel and therefore the scientific party had to come in through the forward cleansing station after they had been out and taken samples.

4. The Forward Bathroom is very hot (Dry 107°F Wet 90°F) and this makes conditions very trying for the cleansing crew. (See also Section VI (iii) 2(d).)

(iii) Protective Clothing

The allowance of protective clothing was found to be reasonably adequate but it had to be augmented with certain items. In particular such special gear as white overshoes and gauze surgical masks, the requirement for these becoming apparent as training for the exercise progressed.

(a) Light Anti-Gas Clothing

This was worn with seaboots and respirators by all decontamination and outside monitoring parties and was found to be generally satisfactory. It could be worn for periods of up to ½ hour in the tropics, even in the Red Sea, without material discomfort. Off Monte Bello, where it was cool, no difficulties were experienced in wearing it for the whole period of decontamination. Two adverse points are that the coats have holes under the armpits and have no means of attachment to the hoods. These defects allow loose contamination to be admitted.

(b) Gauze Masks

600 of these were obtained on the basis of one per man per explosion and in fact a large proportion were used. Their primary use was for equipping parties on the upper deck when the level of loose contamination enabled respirators to be removed, but did not allow some form of respiratory protection to be dispensed with altogether. They were worn by Watchkeepers in the engine room for at least 48 hours after the first explosion and by decontamination parties in the latter stages of their work. In both cases of course, they greatly improved efficiency. They have also been used since the final explosion to enable paint chipping to be carried out without fear of ingestion of alpha or beta emitting fragments.

/(c) White Overshoes . . .

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(c) White Overshoes

As a result of experience in HOTSHOT, 500 pairs of these shoes were obtained from Harwell and it is recommended that they should be included in the normal wartime allowance of protective clothing for all ships. They should certainly be supplied to any other ship carrying out similar trials in peacetime to prevent loose contamination being brought into the citadels or other gas free spaces from the upper deck.

(d) Cleansing Station Packs

Survivor's kits as supplied to DIANA are not ideal for supply to personnel whose clothing has had to be discarded as heavily contaminated. What is really required is a pack made up of a set of action working dress and under-clothes, a pair of shoes and a towel. Spare towels are an essential part of the equipment of a cleansing station. It is also important that large numbers of scrubbing brushes be carried for personal decontamination.

(iv) Monitoring

The procedure laid down in (L)C.A.F.O. 154/55, Appendix D, paragraph 3, was not found to be practicable and it was found preferable for the monitoring parties to be formed, and to work, independently of the section repair parties. The leaders of the teams were mainly senior ratings who would normally be available at Action Stations, and included the C.P.O. Writer and the Stores C.P.O.(S).

2. The Ship's monitoring organisation consisted of four monitoring teams working under the direction of the monitoring officer. Each team consisted of two ratings, a senior one to act as monitor and a junior one as recorder and communications number. They were assigned to parts of ship as follows:-

Party Echo

To monitor within the forward citadel.

Party Foxtrot

To monitor outside the forward citadel, i.e., from the bows to the break of the forecastle.

Party Golf

To monitor within the After citadel.

Party Hotel

To monitor outside the after citadel, i.e., from the break of the forecastle to the stern.

/3. Until such time...

Copy No. 15...

SECTION II - A.B.C.D. (Contd.)

3. Until such time as the outside monitoring parties were required, they backed up those working within the citadels as necessary. In the event, the dose rates received were so low that they were hardly required at all to assist with inside monitoring during the operation.

4. In view of the low dose rates recorded inside the citadels, it has not been considered worthwhile attaching details of them. With a few exceptions they were all well below 10 MR.

5. Attempts were made to check the attenuation factors given in Appendix "E" to C.A.F.O. 154/55 by taking readings on decks immediately below each other clear of all extraneous fittings such as cables, ventilation trunking, etc., but these were only partly successful, probably because the contamination meter is not sufficiently accurate on low readings.

6. As soon as the Scientific Officer reported that his instruments showed that all fall-out had ceased, outside monitoring parties were ordered to dress in full protective clothing and stand by in their respective citadels. After ten minutes had elapsed, they were ordered out on to the upper deck.

7. They proceeded out through the airlocks formed by the cleansing stations, with their monitoring instruments wrapped in polythene bags. These bags incidentally were found very useful for protecting instruments from being affected by pre-wetting water, but no experience was gained in their protective value against contamination as the dose rates were so low. They are, however, an obvious requirement as an anti-contamination measure, see Section IV F (vii) (e).

8. On arrival out on the upper deck, the first job of the monitoring parties was to turn off pre-wetting by sections as ordered by broadcast from A.B.C.D. Headquarters. As soon as this was done they plugged in W/T Portable Control units (which had two fixed positions on deck, to enable them to communicate with A.B.C.D. Headquarters, and which had also been taken out in polythene bags) and commenced monitoring their respective sections.

9. On the upper deck, white spots had been painted on the deck and on the ship's side at regular intervals so that all the monitoring parties had to do was to note the number of the spot and the reading. This ensured that a regular and complete survey of the ship was carried out. Appendix "B" shows a plan of the upper deck marked with these numbers and the readings received on each occasion.

10. The monitoring teams were accompanied by an officer who watched and reported progress. This was found to be important, both from the morale point of view and because it gave the monitoring parties more of a free hand to get on with the job.

/11. It took roughly . . .

/Copy No. 15...

SECTION II - A.B.C.D. (Contd.)

11. It took roughly ¾ hour to monitor the upper deck but this time could, it is considered, have been shortened, had it not been for three factors:-

(a) On both occasions, monitoring had to be carried out in the dark.

(b) All monitoring had to be done with contamination meters.

(c) Communications were not good, there being no red line telephone from the upper deck and only one exchange telephone. Although a radio link was later rigged up, on both occasions (see Electrical Report) some trouble was experienced with this.

12. As soon as a complete survey of the upper deck had been made, monitoring teams marked off particularly "hot" spots with contamination markers and re-entered the citadels to make a more comprehensive report. The first two decontamination parties were then briefed and sent out.

13. After further decontamination, another survey was made and in each case the radioactivity was found to have reached an acceptably low level to enable access on to the upper deck, that is except in one or two places which were roped off, clearly marked with contamination triangles, and left for further washing down in daylight.

(v) Decontamination

Four decontamination parties were formed, each consisting of 1 Leading Seaman and 3 Able or Ordinary Seamen. They were accompanied by an officer to co-ordinate their work, Lieutenant ANDREWS, R.A.N. having volunterred to do this. He proved invaluable as, not only had he been instructing in practical monitoring and decontamination at the Australian A.B.C.D. School for the past 3 years, but he had also assisted in decontamination after Operation HURRICANE. He had also been present at two American atomic tests.

2. As soon as outside monitoring parties had completed their survey of the upper deck and made their reports, the first two decontamination teams were sent out. The parties were not assigned to any particular parts of the ship. They were detailed first to wash down any particularly radioactive spots, followed by the outsides of access doors and air and engine room intakes and then the rest of the upper deck starting from as high up in the ship as possible and working down. As soon as the decontamination officer reported that a party was beginning to show signs of fatigue (this was the limiting factor as the level of radioactivity was insufficient to affect the issue) they were relieved by one of the other two parties. In point of fact, such was their keenness, this was hardly necessary.

3. Decontamination after Operation HOTSHOT took 2½ hours. With the experience gained from this first explosion and because there was a moon on the second occasion, this time was reduced to 1½ hours after the second explosion. This was, of course, the time taken for the initial decontamination to render the upper deck generally useable and did not include certain "hot" spots which were cordoned off and left till daylight.

/4. Decontamination . . .

SECTION II - A.B.C.D. (Contd.)

4. Decontamination of these positions the following morning took from 2 - 3 hours to reduce to an acceptably low level by repeated washing down and scrubbing with a 5% solution of teepol. The only substances which proved considerably resistant to decontamination were some of the non-skid strips on parts of the deck materially contaminated and part of the rubber core cable feeding the scientific instruments on the forecastle (un-prewetted). These had to be removed and thrown overboard.

5. High readings (i.e., over 10 MR and up to 177,000 counts per 100 seconds) were also registered on uncovered gun mountings and torpedo tubes in places where oil and grease had retained the radio-activity. This was removed with shale oil.

6. Lieutenant ANDREWS expressed himself generally very gratified with the effectiveness of washing down in reducing contamination. It appears that one hour's strong hosing down will reduce contamination on an iron upper deck by a further 85%.

(vi) Contaminated Clothing

Because of the low dose rates received, no clothing became sufficiently contaminated to require decontamination. It was merely triced up on lines on deck and left to weather for 48 hours. One point did however emerge in connection with the disposal of contaminated clothing, and that was that ships of this class require to carry at least 12 in No. pattern C.1066 Soiled Clothing Bins in wartime or when carrying out these trials.

(vii) Monitoring Triangles

Efforts to obtain a small supply of these triangles, for marking of radioactively contaminated areas, before the ship left U.K. were unavailing, the ship's attention being drawn to C.A.F.O. 111/51. As this A.F.O. was no longer in force, they had to be constructed from memory. It may be that diagrams of them are being reproduced in the new A.B.C.D. Handbook, not yet received in DIANA, but if not it is suggested that this C.A.F.O. be re-issued.

(viii) Anti-Gas Pavement

This was laid from the bridge access door to the bridge and along the upper deck between the other access doors of the forward and after citadels. In conjunction with the white overshoes, it proved most useful in helping to prevent loose contamination from being brought into the citadels. It is suggested that this material be given more publicity.

/(ix) Shelter Station Organisation

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC

SECTION II - A.B.C.D. (Contd.)

(ix) Shelter Station Organisation

A detailed plan, a copy of which is attached as Appendix "C" to Section IX, was prepared for getting the Ship's Company to Shelter Stations. The organisation worked well and when the first explosion occurred, the time taken for the Ship's Company to go from Action Stations to Shelter Stations was down to 3½ minutes. It is doubtful whether this time can be further reduced.

(x) Action Messing

By the time the operation was completed, the Ship's Company had eaten 7 action mess meals and all variations in the matter of food had been tried. Meals were made as light as possible with plenty of fresh fruit. Meals were eaten at shelter stations, cooks of messes reporting to the galleys for food at the normal meal hours. The organisation proved to be satisfactory; the senior rating in each shelter station was provided with a nominal list of ratings in his station and was responsible for ensuring that each man on the list got his share and that meals were kept for ratings absent on duty.

(xi) Closing Down Citadels

With constant practice, it was found possible to close down the forward citadel in 14 minutes and the after one in 10, from a standing start, and obtain a pressure of up to 2¼" in the forward citadel and 2½" in the after citadel within a further 4 minutes. Manometers were rigged in each citadel, with a watchkeeper on each to report readings periodically, and any significant drop in pressure.

(xii) A.B.C.D. Headquarters

This is not of sufficiently adequate size for a sustained operation of this nature. The A.B.C.D. Officer, the Monitoring Officer, the Engineer Officer (part time), two communications numbers (1 for the W/T link) and the Monitoring Officer's plotter are all based in the A.B.C.D. Headquarters. Despite the provisions of (L)C.A.F.O. 154/55, Appendix "D", paragraph 4, a Monitoring Plotter was found to be essential during these trials and preliminary exercises.

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SECTION II - A.B.C.D.

APPENDIX A

H.M.S. DIANA - STATEMENT OF REQUIREMENTS FOR PREPARATION FOR SPECIAL TRIALS

Officers Present:

R. Anscomb, Constructor	D.N.C. Dept. (Chairman)
C. Argles, Captain	H.M.S. DIANA
M. Butler, Lt. Cdr.	" "
J. Judge, Lieut.	" "
L. Pascoe, Cd. Elect. Officer	" "
N.G. Eldridge, Asst. Constructor	D.N.C. Dept.
C.J. Rhodes, Commander	E.in C. Dept.
M.A. Spencer, Lt. Cdr.	M.E.D. Dept.
F.P. Chambers, Ldg. Draughtsman	E.in C. Dept.
A.E.M. Phillips, Constructor	M.C.D. Dept.
W.E. Murch, Foreman of Yard	M.C.D. Dept.
S.T. Best, Foreman Electrical Branch	E.E.M. Dept.
H. Goudge, Commander	E.E.M. Dept.

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Ship's Organisation, Training Courses, etc.

In this connection Mr. Anscomb read out the following extract from an American Report :-

" Looking back on the operation, we can see that the most fruitful steps taken were in the extensive training prior to the tests. By the time "Phillip" arrived in the operating area we had a trained crew - monitors who could use their instruments with proficiency, repair parties who could button up the ship and get the washdown system going in record time, and a group of officers and men who could really pull together as a team. The staffs of CJTF 7 and CTG 7.3 were most helpful and instructive in satisfying their commands and insuring us of our ability to cope with the radiological problems that we might encounter.

The contribution of the following factors to effective radiological defense were amply demonstrated in this operation:

An effective washdown system.
All fire and flushing pumps in good working order.
Availability of radiac instruments and the personnel to operate and repair them.
Ability to make the ship a "gas tight envelope".
Knowledge on the part of command of the intensity required over a period of time to reach tolerable dosage limits.
Manoeuvring of the ship (weaving) at a speed to give 20 to 25 knots of apparent wind when decontaminating with the washdown system.
Indoctrination of all shipboard personnel in radiation exposure tolerances to eliminate unfounded anxieties.
Decontamination stations available for immediate use.
A near maximum supply of fresh water available to decontamination stations. It should be noted that salt water should be used when it is safe and when it is necessary to insure a good reserve of fresh water for

SEC[illegible] UK [illegible]

SECTION II - A.B.C.D.

APPENDIX A (Continued)

the occasion when the sea water around the ship will be found heavily contaminated.

Thorough training of shipboard personnel in detection and decontamination procedures and a basic understanding of the need for and employment of all the other items listed above."

Mr. Anscomb said that he realised it would not be easy at this time to organise courses and exercises for the new ship's company, but emphasised that they must be arranged in the very short time available.

Work to be undertaken by the Dockyard during Refit

1. Forward and After Citadels to be made air tight, but not necessarily hermetically sealed (D.N.C. will provide an acceptable standard of leakage).

   Refit all external watertight doors, hatches, scuttles, vent flaps, etc.

   Additional clips to be fitted to the ventilation flaps and elongated holes provided for the hinge pins as necessary to ensure tight fitting of covers. Clips should be not more than 12" apart and 6" from the corners of the covers.

2. Install improvised pre-wetting system (D.N.C. will provide further information).

   A necessary pre-requisite for this is a thorough refit of the fire main, valves, and hull and fire, and fire and bilge pumps.

   N.B. The above two requirements are most important and special attention will have to be paid to them.

3. Install 6 Porton Filters which will have been modified by the removal of the carbon filter elements. Size of units 19" x 19" x 6' 2" high. Units fitted with 7" dia. intake opening at the top. Length of trunk from top of unit to outside air should not exceed 10 ft. D.N.C. will provide further details.

Suggested positions are:-

Forward Citadel (Four units)

(a) One in each fan compartment abreast B gun with inlet from deck over.
(b) One in the space vacated by the Officers' Food Lift with inlet in side screen.
(c) One in the Wardroom taking its supply from the existing natural exhaust above.

After Citadel (Two units)

(a) Two in the immediate vicinity of the Sick Bay with inlets in the deck over.

Filters from the Units to be thrown overboard when they become "hot".

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SECTION II - A.B.C.D.

APPENDIX A (Continued)

4. Special attention to be given to steam tightness of all joints and glands, etc., it being vitally important to keep the humidity of the machinery compartments down.

5. It is necessary to make the turbo-blower and boiler casing reasonably air tight, but not to hermetically seal them. In the turbo compartments and boiler casings there are quite a number of largish holes which can be sealed up without undue difficulty.

6. Seal the annular openings around the funnels and fit new openings in the deck alongside the funnels which are to be provided with covers which can be operated from the Boiler Rooms. (D.N.C. will provide a drawing).

7. Fit 6" 'U' traps in all main outlets from the urinals, bathrooms, and washplaces where not already provided to ensure maintenance of positive pressure in the citadels.

8. Fit Seamen's heads and bathroom (48-56 Port) or adjacent P.O.'s bathroom and crews bathroom (90-94 Port) as decontamination bathrooms.

   This involves sealing off certain parts of the ventilation trunking, making the compartment air tight, cutting doors, fitting curtains, providing air locks etc. (D.N.C. will provide further information after discussion with Dockyard and Ship's Officers).

9. Undertake A. and A. 20 - fitting of Staff Office as A.B.C.D.H.Q.

10. Undertake A. and A. 88 - gas curtain to Gun's Crew shelter.

11. Undertake A. and A. 99 - trunked air to forward diesel.

12. Undertake A. and A. 203 - extension of M.S.O. lobby.

13. Undertake A. and A. 223 - new ventilation system in Ops. Room.

The following item is desirable but not essential :-

A. and A. 57(b) - Fan exhaust to after crew's messes. The situation is that a fair amount of work is involved in this alteration and provided the ship leaves the internal hatches open for recirculation purposes, there is no need for this item to be done.

Testing and Trials

1. Boiler Casings and Turbo-Blower Compartments operational air test. (using suction on boiler rooms).

2. Gas Citadels

   Preferably using exhaust fans and incline 'U' tubes for measuring pressure difference.
   By measuring the pressure difference between inside and outside an equivalent leakage area can be deduced. D.N.C. will give an acceptable figure for this leakage area.

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SECTION II - A.B.C.D.

APPENDIX A (Continued)

3. Closing Down Trial with Porton filters running to be undertaken towards the end of the refit.

D.N.C. will provide further information and send officers to this trial.

4. Initial and final trials of pre-wetting system

Work Required of Ship's Officers

1. Thoroughly overhaul closing down organisation.

2. Check all recirculation flaps and other fittings required for closing down and communicate defects to Dockyard.

3. Draw Dockyard Officers' attention to all known breaches in the gas citadels. In particular check that the cartridge return chutes to the magazines can be sealed off externally and are fitted with flaps for opening into the messes.

4. Arrange for all necessary training courses and exercises for the new ship's company.

5. Read report of "Defender's" closing down trial under tropical conditions and consider the organisation for the rotation of watches, etc. in the engine room and boiler rooms.

Note:
1. No. 1 boiler room has access to the forward citadel
2. No. 2 Engine room has access to the after citadel.
3. No. 2 boiler room has access to the midships deck house.
4. No. 1 engine room has access to a small lobby amidships.

6. Arrange for the temporary landing of one torpedo as weight compensation for the Porton filters etc.

7. Ensure that all canvas covers are available for such items as fresh water tank and other air escapes.

Operational use of Equipment

1. Advice will be given by D.N.C. on the use of the Porton filters.

2. Subject to the result of the closing down trials, all fans should be run at half speed when on recirculation.

3. For the purposes of this exercise, internal hatches should be kept open to assist recirculation.

4. The necessity to use the rectifier in the after C.R.D.F. room during the trial to be investigated by Ship's Officers. D.N.C. to consider effect of this on after recirculation system and decide on any necessary re-arrangement.

5. The suggested use of the bridge awnings to reduce the contamination of bridge fittings to be considered by Ship's Officers.

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SECTION II - A.B.C.D.

APPENDIX A (Continued)

Special matters still under consideration

1. Temporary fitting of 40,000 B.T.U. air conditioning units for one or two selected positions in the ship. These items measure 3'6" x 2' x 6' high.

Programmes

1. Initial air test on Citadels and trial of pre-wetting system should take place not later than 15th January.

2. Assuming that other considerations allow of the refit being extended by two weeks, the final air test on citadels, boiler casings, turbo-blower compartments, etc. should be completed by the 19th February, in which case :-

3. The initial closing down trial should be completed not later than 26th February.

Admiralty Contacts

D.N.C.	- Mr. Anscomb,	Tel. No. Tennyson 0101,	Ext.	0397
	Mr. Eldridge	" " "	"	0688
E.inC.	- Commander Rhodes,	Tel. No. Tennyson 0101,	Ext.	0085
	Commander Grey,	" " "	"	0661

Captain Argles raised the question of security and the classification of this exercise, and suggested that a statement be issued to the effect that the DIANA will be sent to observe certain trials from a safe distance. This would allay any fears and rumours on the part of the ship's company, etc. Mr. Anscomb and Mr. Eldridge undertook to raise this question with the appropriate authority.

Mr. Phillips asked whether any space would be required for measuring instruments, etc. It was thought that space would be required for one scientist and also for the instruments, which were portable. A certain amount of electrical power would also be required. Mr. Eldridge undertook to obtain full details of this requirement.

C.W. Goudge raised the question of Wave Guide Dryers and it was agreed that facilities should be provided for switching them off separately. Mr. Anscomb undertook to seek confirmation from D.E.E. and D.R.E.

The use of the Radar Novelle air conditioning units would also have to be investigated by the Admiralty.

Captain Argles questioned whether :-

(a) The additional work required to prepare DIANA for her special duties would be done at the expense of normal refitting work already being undertaken in the ship in order to complete the refit by the present date of 22nd February, 1956.

H.M.S. DIANA's REPORT ON OPERATION MOSAIC

SECTION II - A.B.C.D.

APPENDIX A (Continued)

or (b) The refit would be extended to ensure the completion of all normal refitting work and the additional commitments observing that this would involve a corresponding reduction in the ship's working up period prior to the special trials.

After discussion Mr. Anscomb gave the following policy line, Admiralty authority for which would be sought without delay:-

(i) The standard and amount of normal refitting work to be undertaken in the ship should not be affected by the additional commitments.

(ii) After allowing for overtime, limited shift work, etc. it would be unrealistic to expect that the normal refitting and the additional work (the nature of some of which results in disruption of the normal refitting programme) could be completed in the normal refitting period.

(iii) An extension of two weeks on the refit period would involve a corresponding reduction in the work up period, but would not prevent DIANA from arriving in Australia in good time for the special trials.

(iv) In view of (i), (ii), and (iii) A.S. Devonport should forward a signal to the Admiralty on the lines that assuming a fortnight's extension to be acceptable the normal refitting and special work in DIANA can be completed by 11th March, 1956 subject to delay in certain other work and/or use of overtime, limited shift work, etc.

In response to a question concerning trials, exercises, training etc. Capt. Argles was advised by Mr. Anscomb to communicate with Cdr. D.S. Lawford of D.T.S.D. who is a member of the working party.

The question of the availability of pumps for the initial pre-wetting trials was raised and it was emphasised that at least the electrical hull and fire pumps must be available by the date quoted.

Lt. Cdr. Spencer raised the question of drawing office work and stated that if any drawings were required they should be informed now, as it would be extremely difficult, if, at a later stage, the Admiralty suddenly decided drawings were required. Mr. Anscomb replied that he had had a directive from D.N.C., that as much as possible of this work should be on an improvised basis so that all fancy schemes would be resisted.

Mr. Phillips assumed that the items for this trial would be coded separately and asked that S.339s for this particular trial should also be sent in separately and not mixed up with ordinary ship defects. There were not other points to be discussed and the meeting closed at 11.50.

(Sgd.) R. Anscombe

CHAIRMAN
20.12.55.

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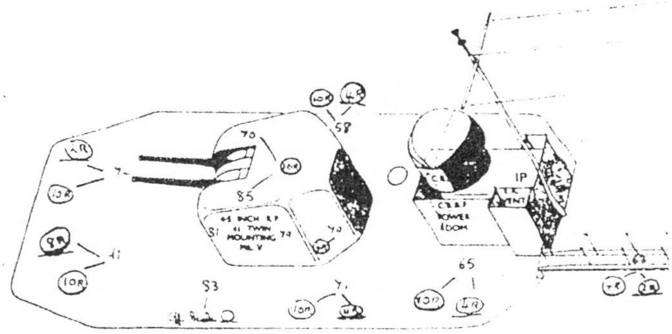
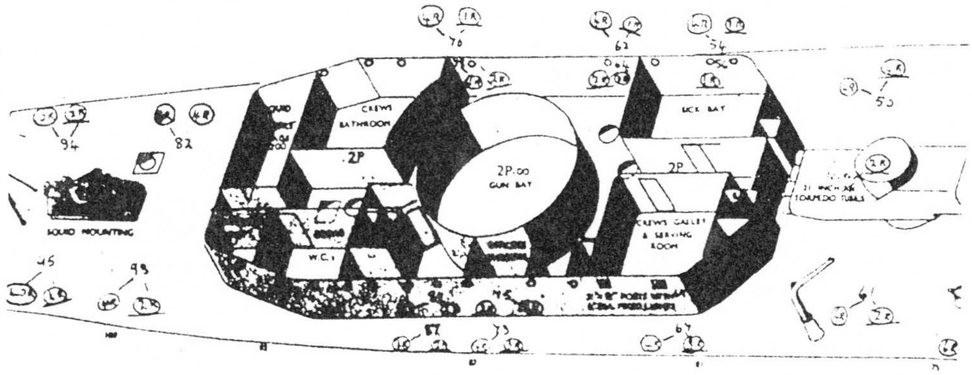
APPENDIX D TO SECTION II

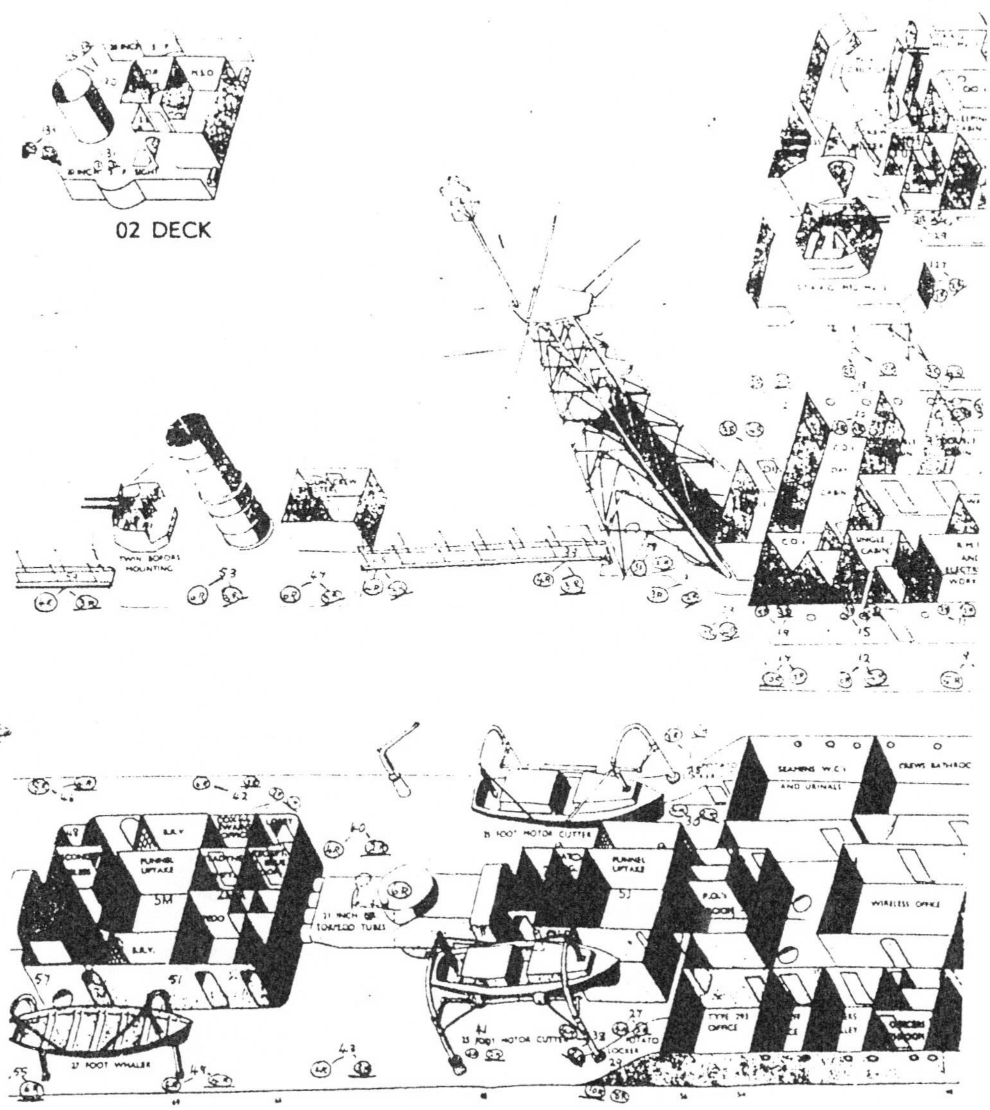
(R) = FIRST EXPLOSION

(R) = SECOND EXPLOSION





APPENDIX B TO SECTION II



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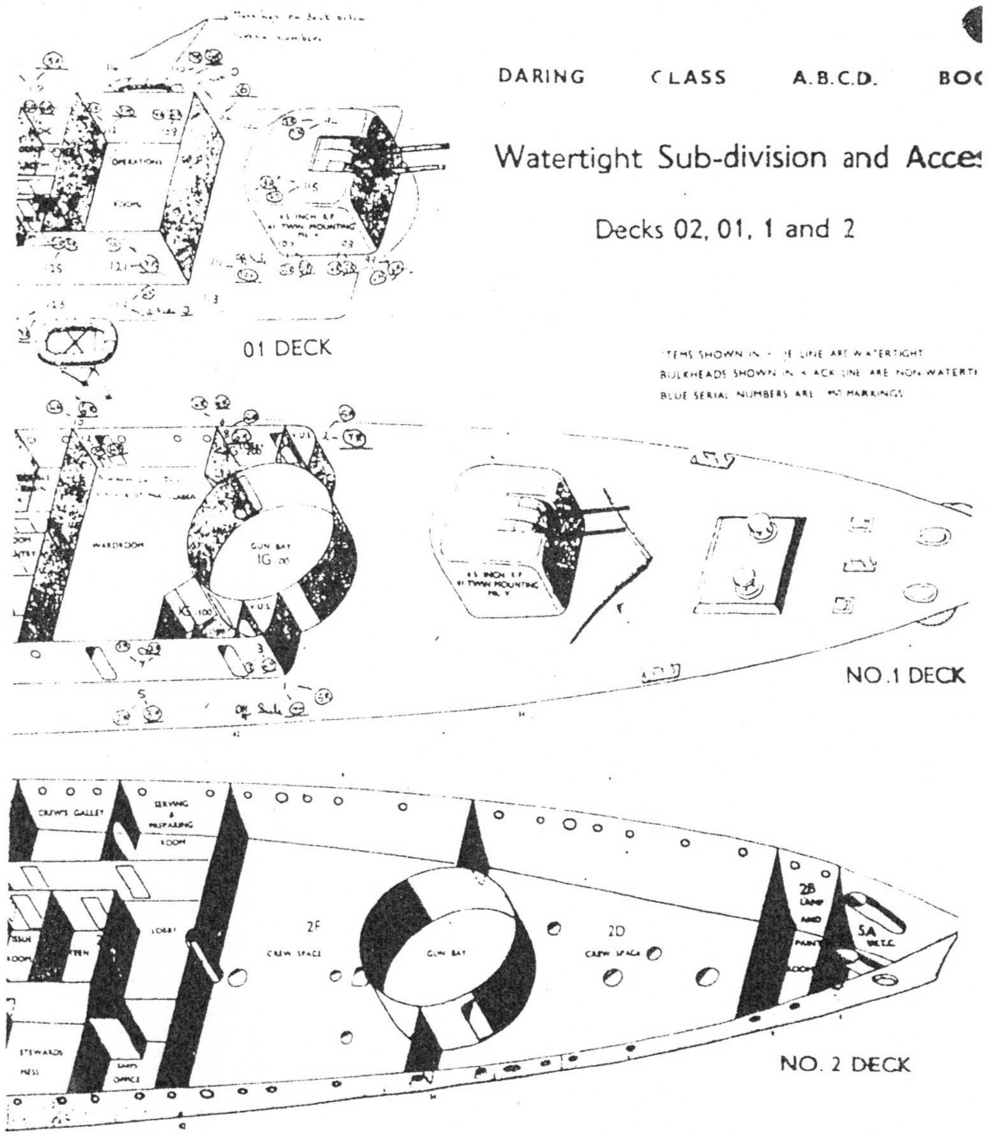
APPENDIX B TO SECTION II



SECTION III: - PRE-WETTING

A - OPERATIONAL APPRECIATION

The lessons learned from the use of pre-wetting as fitted may be summarised as follows:-

2. The system places a heavy burden on the fire main service resulting in low nozzle pressures, even if air conditioning and various cooling water supplies are shut off.

Effects

(a) Nozzles must be set so as to be efficient at one condition of relative wind. That is; weaving either side of true surface wind.

(b) Nozzles must be too jet like hence the coverage is a little reduced but most important the "time to wet" is increased. In this case 10 - 15 minutes time to wet was usual.

(c) Loss of "fightability" in otherwise air conditioned compartments.

3. It is connected to the nozzles by means of hoses affixed to the usual upper deck valve positions.

Effects

(a) At normal Action when under the control of the Gunnery Officer the "switch on party", who are the close range weapons crews take some 4 - 5 minutes to leave their action station, switch on the pre-wetting and close up again.

4. Total time to the ready condition from start is thus 12 - 17½ minutes or 120 to 175 miles of enemy travel at 600 knots.

5. The localised spray is injurious to the fighting efficiency of the men and material in open directors and weapon mountings. In view of the current tactical doctrine (F.O.T.I. 1601 dated 4-?-56) and of the clear necessity for being able to meet conventional air-attack in, at least, light "dry" fall out (C.B. 03016 (1955) Sections 502 and 503 by inference) this is considered to be a matter of great importance. The measures taken by the ship's staff and the results acheived are set out in detail in Section VIII of this report.

6. Arising from 2,3 and 5 above it is clear that three important requirements exist.

(a) Pre-Wetting must be switched on very quickly and be of such capacity as to wet speedily.

(b) Working pressure must be high enough to make relative winds of, say, 30 knots acceptable from any direction, and 50 from right ahead.

(c) Pre-Wetting must only be used when actually required.

7. The requirements 5(a) and (b) above at once suggest a permanent built in system with its own associated pumping system operated centrally with direct communication to the Bridge and/or Operations Room.

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H.M.S. DIANA'S REPORT ON OPERATION MOSAIC

SECTION III: - PRE-WETTING

A - OPERATIONAL APPRECIATION

8. 6(c) above immediately poses a warning system which it is considered should be divided into three parts.

At Masthead

(a) Gamma counting probe.

(b) Open ended tube bringing air samples down to suitably sited scintillometers.

Under Water

(c) Gamma counting probe.

Each of the above should display its information in as startling a mannner as possible on the Bridge and in the Operations Room. Actual quantitive readings may be restricted to a display in A.B.C.D.H.Q.

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SECTION III: - PRE-WETTING

B - EFFICIENCY

The effectiveness of pre-wetting was amply demonstrated and showed that it reduced contamination by a factor of the order of 80%. Two examples can be given of this and attention is drawn to Appendix 2, table 9 of section entitled "The Armament".

(a) Shortly after the first explosion, one of the three pre-wetting hoses on the Starboard side of the quarterdeck blew out due to a defective coupling, hence a section of deck remained dry. On monitoring, this patch showed 40 m.r. per hour, whereas the other side of the quarter deck gave a reading of just under 10 m.r. per hour.

(b) After the second explosion, the port forward corner of M. 2. S.T.A.A.G. deck, which was warped so as to be higher than the rest, and greasy, had escaped being pre-wetted, owing to the shielding effect of a low bulkhead. This small area (some 3 square feet) gave a reading of more than 10 m.r. per hour on the contamination meter number 1, that is to say off scale, whereas the rest of the deck which had a continuous stream of water washing over it gave a reading of only 2 m.r. per hour.

2. It would not appear that there is any significant difference between its effect on vertical as opposed to horizontal surfaces, although the light amount of fallout received was hardly enough to give any validity to this conclusion.

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H.M.S. DIANA'S REPORT ON OPERATION MOSAIC

SECTION III: - PRE-WETTING

C - ORGANISATION

(i) Pumps and Water Supply

To supply sufficient water to the pre-wetting system in 'DIANA' it is essential for all the pumps fitted for supplying the fire main to be running, viz:- 2 in No. Turbo Fire and Bilge pumps, rated at 40 tons/hour each. 3 in No. Hull and Fire pumps, rated at 20 tons/hour each.

2. All pumps were in a satisfactory condition for both trials, with the exception of A, F and B pump, the impellor of which was found slightly choked following 'HOTSHOT'. In the period between leaving U.K. and the trials, two pumps had defects to be made good. Floating weed was a persistent problem in the Monte Bello area, and pump strainers choked and required cleaning at intervals of approximately 4 hours. There was therefore a potential risk of any pump being inefficient when required.

3. The highest pre-wetting pressures were recorded during a test between the two trials and were:-

No. 1 H. & F.Pp	- Discharge	40 lbs in^2.	
No. 2 " "	"	40 " "	
No. 3 " "	"	40 " "	
No. 1 F. & B."	"	40 " "	at 7,000R.P.M.
No. 2 " "	"	45 " "	" 7,000 "

Fire Main Pressure 30 to 36 lbs/in^2.
Pressure at pre-wetting breeching piece gauges, 25 to 30 lbs in^2.
All pre-wetting sprays in good condition.

4. The above figures, obtained in harbour, are better than those which could be obtained at sea, when some fire main supplies are essential for other purposes, viz:-

(a) Steering Gear Cooling System.

(b) Boiler Room blower cooling - used to boost the blower circulating pumps.

(c) Air conditioning machinery cooling water.

Note:- While (a) and (b) are obligatory while the ship is steaming, (c) was in fact shut off for a large part of the trials, until temperatures of the 293 Radar equipment and the W/T office necessitated restarting air conditioning to avoid material damage.

5. Air conditioning water requirements are considerable, and cause a drop of about 3 lbs/in^2 in fire main pressure, but must apparently be considered an essential service in tropical climates.

SECTION III: - PRE-WETTING

C - ORGANISATION

(ii) Pre-Wetting Hoses and Fittings

The use of canvas hoses when, as was the case prior to these trials, the system must remain rigged for a considerable period of time, involves a degree of rough treatment of hoses rigged or positioned in part of the ship where considerable traffic occurs. Although marking hoses and fittings for rapid rigging, together with a well practiced team enables the pre-wetting system to be rigged in approximately 2 hours, careful rigging is essential. This was proven in the first trial (HOTSHOT), when a breeching piece and hose became disconnected after pre-wetting was started, not only resulting in an un-pre-wetted area, but also in a serious loss of fire main pressure.

2. Storage space required for unrigged pre-wetting hoses and breeching pieces in 'DIANA' occupied a part of 'X' gun deck, but will prove much more difficult to arrange when the ship is normally operational.

3. Spray/jet nozzles and brackets were liable to minor damage and maladjustment which necessitated regular testing of the system, with consequent closing down of the ventilation to prevent ingress of water; failure to carry out such testing would certainly have led to ineffectual pre-wetting.

(iii) Operation of Pre-Wetting System

The organisation for turning on and off the pre-wetting in 'DIANA', for purposes of operation MOSAIC, was controlled by the A.B.C.D. Officer from A.B.C.D. H/Q. Turning on or off sections of the pre-wetting was carried out on the weather decks by the pre-wetting party of 2 men, acting on broadcast orders. The system is divided into 3 sections, forward, midship and after, and is always turned on or off section by section.

2. The pumps are worked as follows:-

(a) Both turbo pumps are run up to maximum output, and discharge into the fire main before machinery compartments are shut down.

(b) The three motor pumps are started, with No's 1 and 3 pumps discharging into the fire main, and No.2 pump overboard discharge open to sea. With these single-speed A.C. Motor pumps no speed control is provided, and it is necessary to control fire main pressure by means of one pump's overboard discharge. This duty is carried out by the rating stationed a No.2 pump, who can hear the A.B.C.D. Officer's orders through the ship's broadcast loudspeaker sited in the Electrical Workshop, and can therefore anticipate increases in fire main pressure.

3. The control of pumps by this method worked satisfactorily during both trials.

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SECTION III: - PRE-WETTING

C - ORGANISATION

(iv) Conclusions

(a) - Pumps

A margin of one pump at least is required to provide against pump failure and to allow for maintainance of the much used machinery.

2. The quantity of fire main water which must be diverted to the various other essential services should be considered in the estimates of the pre-wetting water requirements.

(b) - Pre-Wetting System

A temporary arrangement, as used in these trials, requires constant maintenance effort to retain efficiency, and is vulnerable to damage and maladjustment, in which cases the water available is not used to the best advantage, and the overall efficiency of the system is impaired. A permanent piped system, directing water to the requisite exposed positions is necessary to overcome these difficulties.

(c) - Control of Pre-Wetting

By the use of a permanent pre-wetting main, control of turning on or off could be more satisfactorily carried out from a position inside the citadels, preferably as adjacent as possible to the controlling pump positions.

(d) - Plastic Hose supplied by H.M.S. Phoenix

One length of plastic hose was provided for comparative tests during these trials. This length of hose formed part of the amidship section of the pre-wetting system and was positioned where it was subjected to considerable amount of hard usage. The hose showed no evidence of hard treatment and no leaks developed. Possibly due to its lack of minor leaks or seepage it enduced a higher contamination and resistance to decontamination than adjacent canvas hoses.

(e) - Spurnwater

During the trials before the operation it was found that pre-wetting water collected along the spurnwater and spread over the upper deck with the movement of the ship. In consultation with the Senior Scientific Officer it was decided that it was not acceptable for large areas of contaminated water to collect on the upper deck during the operation, and the spurnwater was accordingly removed. A second factor that was also taken into consideration was the fact that wood readily absorbs contamination and is very difficult to decontaminate. It is proposed that consideration be given to fitting metal spurnwaters, as is done in some frigates.

SECTION IV: - ENGINEERING

A. - INTRODUCTION

(i) Objects of Trials

To investigate the entry and expulsion; retention and distribution of radioactivity in machinery spaces and systems after receiving fall out, and any decontamination problems arising subrequent to the trials.

2. Compartments or machinery for which specific trials were arranged were :-

A engine room and B boiler room
B boiler
The evaporator in B boiler room
Circulating water systems
No. 1 Diesel Generator.

3. Trials conditions for main machinery compartments :-

(a) Steaming under fully shut down conditions
(b) Steaming with whole or part of the ventilation open.

4. Concurrently with these investigations it was required to assess the problems arising from steaming under the above conditions and the use of the equipment provided for the watchkeepers. Condition of heat and humidity were to be determined.

(ii) Selection of Compartments and Machinery in paragraph 2 above

The access hatches to A Engine Room and B Boiler Room are situated outside the two Citadels, therefore the use of these hatches during the trials will not affect the pressure in the latter or introduce contamination directly into them.

2. No. 1 Diesel Generator situated in a compartment inside the forward citadel has been fitted with a trunked air supply from the weather deck. The air inlet is provided with a filter.

(iii) State of Machinery Compartments not manned during the trials

A Boiler Room and B Engine Room were unmanned and shut down throughout the trials period, during which period the ship was steamed on the starboard shaft and one boiler only.

(iv) Equipment provided to enable the Engine and Boiler Room Watchkeepers to operate the machinery under shut-down conditions

A Northey air compressor is installed in A Engine Room and B Boiler Room. Each compressor takes an air supply from a mushroom head fitted to the emergency access hatch to the compartment. This air is led through a Porton filter to the compressor. The compressed air is passed into a 4-connection manifold, and thence to each watchkeeper through a 50' length of air hose.

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SECTION IV: - ENGINEERING

A. - INTRODUCTION

(iv) Equipment provided (Continued)

2. Watchkeepers wear a P.V.C. one-piece suit to which the air hose is connected. The intention was to provide for four men in each compartment.

3. 20 of these suits were supplied and although exhaustive trials could not be carried out in the time available it was hoped that watches of at least one hour's duration would be possible. It was intended that the Ship's Staff would develop their own technique for using these suits.

4. Fresh water showers were provided adjacent to the access hatches to enable men to decontaminate themselves before entering the compartments.

5. It was intended that all watchkeepers should relieve from the forward citadel and to provide for ventilation and breathing air while passing to and from the citadel and machinery compartments, six hand-bellows were supplied.

(v) Pre-wetting

To meet the requirement for water supply to the temporary system fitted, the use of all the pumps in the ship is essential, viz :-

Two Turbo Fire and Bilge pumps
Three Electric Hull and Fire Pumps.

SECTION IV: - ENGINEERING

D. - PROTECTIVE SUITS FOR WATCHKEEPERS

(i) Ventilated Suit Equipment

Time and inexperience of personnel in steaming the ship prevented full scale trials of this equipment being carried out before leaving the United Kingdom, but short functional trials at Plymouth gave every indication that the equipment would meet the requirements.

2. Opportunities were taken on passage out to familiarise personnel with the wearing of these suits, and eventually with steaming the ship under closed-down conditions.

3. When sea and air temperatures rose above 80° F., conditions inside the suits worsened considerably due to the heated air supply. The compressors themselves also ran very hot, and, when one motor's high temperature cut-out operated after only half an hour's running, concern arose over their ability to run for long periods.

4. From the evidence available, it appeared that the compressor motors were overloaded, but no quick remedy could be found. The heavy non-return valves on the discharges were removed, as their function was not apparent; a heavy oil recommended in the Maker's handbook was used in the gearbox, and the high-temperature cut-outs in the starters were gagged.

5. In the event, both compressors ran faultlessly for all the periods for which they were required, sometimes 3-4 hours under shut down conditions and a further ten hours under cooler conditions.

6. The temperature of the air leaving the compressors was fortunately reduced considerably in the hoses to the suits; even so it was hotter than desirable, averaging about 115° F. Lagging the air suction pipes, particularly at the crowns of the compartments, was tried, but had no measurable effect. A simple cooling water jacket was fitted by Singapore Dockyard to the discharge of each compressor (in 24 hours) which helped to reduce the air temperature slightly. Details of motor and compressor performance are given in Appendix D.

(ii) Suits

Due to the hot air entering the suits the wearers perspired freely (an average of 2 pints per hour). This moisture accumulated at the extremities and the inside humidity, initially low, gradually increased, with corresponding discomfort to the wearer. Efforts were made to increase the air flow through the suits; the outlets at wrists and ankles were much enlarged and unused air connections on the manifold were blanked. These measures, together with the reduction in the number of watchkeepers (see 'Organisation') improved conditions, but the air flow was still insufficient.

2. It was hoped that one hour watches could be kept in the suits, but trials indicated that the maximum period for conscientious watchkeeping, allowing for the watchkeeper to return to the undressing station, was 35-40 minutes.

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SECTION IV – ENGINEERING

D. – PROTECTIVE SUITS FOR WATCHKEEPERS

(ii) Suits (Continued)

3. One of the most troublesome features of the suits was the noise made by the entering air. A baffle is fitted in way of the wearer's left ear, which should not be removed, but which considerably assists in the production of noise. The use of telephones is almost impossible, and of intercom systems extremely difficult, and this is one of the major problems in these suits. Even telegraph gongs could not be distinguished. This noise was also very tiring and was probably a significant factor in a man's endurance, especially when combined with the inevitable slight sense of claustrophobia.

(iii) Boots

Victualling Stores galley boots were worn by all watchkeepers, and proved entirely suitable for the purposes of this trial. Laces were not used.

(iv) Gloves

No suitable gloves were available from service sources and efforts to make gloves to our own specification failed. Asbestos cloth held in the hand proved satisfactory, and no suits were damaged by heat. One rating blistered his hand on a hot valve handwheel but his suit was undamaged.

(v) Harness and Air Hose

A satisfactory method of wearing a harness provided for use with Pattern 230 breathing apparatus was devised. The air hose Pattern 2314 is heavy and cumbersome to handle when wearing a suit. Individual air shut off cocks were not used as no suitable light weight cocks were available. They would be an advantage when a hose is no longer required to be connected.

(vi) Vision

Except for reading some of the instruments provided for the trials, vision proved adequate for normal purposes except when using the hand bellows provided for transit between citadel and machinery compartments, when severe misting occurred.

(vii) Hand Bellows

Only six were provided for use as above; this number was much below the requirement, which should be one per suit. While it is quite possible for a fit man to leave the machinery compartment and proceed to the undressing station without a hand bellows as is stated in later paragraphs, delays in undressing occurred, and without them serious discomfort may be caused. Contaminated bellows should not be brought

B. - PROTECTIVE SUITS FOR WATCHKEEPERS

(vii) Hand Bellows (Continued)

inside the citadel and unless each man has his own, watchkeepers about to go on watch may be without a set. The effort required to use the bellows is increased by their tendency to distort and buckle.

(viii) Watchkeepers Dress

Although the wearing of overall suits is desirable in machinery spaces, watchkeepers were permitted to wear the clothes in which they felt most comfortable. Experience showed that shirts and shorts were most favoured. A thick shirt protects the skin of the shoulder against the heat of the suit where it is pressed down by the weight of the hose and harness, sleeves and trousers tend, however, to restrict the exit of air from outlets.

(ix) Radiant Heat

The suits themselves become uncomfortably hot to the skin. When moving to a more heated part of a machinery compartment the additional temperature was more immediately noticeable than in the other patterns of protective suits.

(x) Vulnerability of Suits to Damage

Three suits were torn or split during exercises before the actual trials and a successful repair could not be made. In each case damage was unknown to the wearer. No suit became unusable through use or heat and all suits had a large amount of usage.

(xi) Dressing and Undressing

A difficult operation to undertake in a hurry and requiring at least one undresser per man. Knives were placed in machinery compartments in case of a casualty while under shut down conditions.

(xii) Protective Clothing used by Engineering Department other than P.V.C. Suits

The only pattern of protective clothing supplied to the ship which was at all suitable for watchkeeping with ventilation open, and for use by men opening up ventilation flaps, comprised 24 Green Gaberdine type suits; understood to have been the pattern supplied for operation "Hurricane". These suits, strong and rather heavy owing to reinforcements at the knees, elbows and shoulders can be worn with respirators for periods exceeding two hours in partly ventilated machinery compartments. The lack of a hood or arrangements for securing a hood presents serious difficulties in the protection of the wearer's head and neck and renders them useless for 100% protection. It was intended to wear a respirator and anti-flash hood with an oilskin hood over that. This rig was in fact worn by the ventilation opening up party, some members of which did receive very small amounts of contamination passing between the neck of the suit and the oilskin cap. This dress cannot be considered to

SECTION IV: - ENGINEERING

(xii) Protective Clothing (Continued)

offer full protection to watchkeepers. The pattern suit issued by U.K.A.E.A. to the A.R.L. representatives on board appeared most suitable for machinery watchkeepers. It is made of a lightweight white fabric and has a fitted hood. The Senior Health Physics adviser for the operation was consulted and arranged for 20 of these suits to be supplied to DIANA. These suits worn with respirators, for which lightweight resin wool filters were also supplied, may be worn for periods in excess of 2½ hours without undue discomfort. They are also suitable for entering a compartment or confined space such as a boiler air casing which may retain radioactivity. A light suitable undergarment made by Aertex and resembling a pair of combinations with short sleeves and legs was also provided for trial and was most comfortable.

(xiii) Medical Officer's Comments on physical aspects of experiences with Protective Clothing

During the trials very few premature reliefs from watchkeeping were required, mostly in the early stages of training. Distress symptoms were mainly: fatigue, faintness, headache, respiratory distress, abdominal discomfort or sense of claustrophobia. It is noteworthy that none of the normal methods of resuscitation are available for treating casualties while airborne hazards persist and such casualties would require to be brought within the citadel with some difficulty before any first aid could be given. No lesions suggestive of either chemical or radiation burns were sustained, neither was any significant whole body radiation incurred by exposed personnel.

(xiv) Conclusions regarding the use of Ventilated Suits under Shut Down Conditions

The trials carried out with this prototype equipment in DIANA have shown that such a system will work and has much scope for development. It is emphasised that the organisation and implementation as described were conditioned, above all, to trials requirements, and much of what was prepared before hand, done during, and cleared away at leisure afterwards, would present much greater problems under action conditions. This particularly concerns the limitations and spaces for providing ready use stowage of a large number of suits, the size of decontamination centres and undressing stations.

Proposed requirements for ventilated suits :-

1. A cooled air supply to suits in hot climates; the reverse may be required in the Arctic.
2. Lightweight air hoses and fittings and harness attachments to suit quick acting hose connections, and a control cock.
3. Air entry to be as silent as possible to relieve fatigue and resolve communications problems.
4. Asbestos mitts; these should be easily removable to enable hands to grip small objects e.g. pencils.
5. Boots, easy to put on and take off, easy to decontaminate, to have thick soles in view of the high temperature of floor plates. (Duckboards on floorplates reduce fatigue in legs and feet.)

SECTION IV: - ENGINEERING

B. Protective Clothing

(xiv) Conclusions (Continued)

6. Simple fastening arrangements to enable dressing and undressing to be performed rapidly; if practicable the wearer should be able to carry out these functions without assistance, and thereby dispense with undressers and eliminate the problems of a man becoming a casualty inside a suit which is difficult to remove. The speed of dressing is most important when closing down initially.

7. A suitable absorbant undergarment for use in hot climates: overalls would be more appropriate in colder climates.

8. Material of suit to be as strong as practicable and must be repairable with ship's resources.

9. Material such as P.V.C. has the advantage of being easily decontaminated and also washed and disinfected after use.

10. An improved design of bellows is essential, preferably attached to the suit harness permanently to avoid the contamination risk when changing over air supplies and also the hazard of the open end when passing along weather deck.

(xv) Provision of Upper Deck Showers

Although not used for these trials they would be useful in the event of heavy fall out if sited out of the prewetted area. In DIANA this would have required the Engine Room showers to be inside the lobby, and the boiler room showers to be well inside the cross passage: even so these positions would be far from perfect.

SECTION IV: - ENGINEERING

C. - FINAL ORGANISATION FOR ENGINEERING WATCHKEEPERS

Originally it was intended to have three watchkeepers and one officer or observer in each compartment. The time limitation of 35 minutes, and the limited number of suits available (17 out of 20), however, made it necessary to reduce the number to two watchkeepers per compartment; 1 E.R.A. and 1 L.M.(E) in the Engine Room and 1 P.O.M.(E) and 1 L.M.(E) or M.(E) in the Boiler Room. This made possible a period of approximately 2½ hours steaming with all ventilation shut. Thereafter watchkeeping was carried out in the U.K.A.E.A. suits with partial ventilation open. It was not known how long the period shut down would be, but the longest period (of 13 hours) during HOTSHOT was longer than had been envisaged, and all protective suits, including a number of the 'Hurricane' pattern, were used.

2. The organisation, dressing and relieving of watches was controlled from the A boiler room cross passage inside the forward citadel. All watchkeepers left from, and returned to, the forward citadel only.

3. The seamen's bathroom off the port passage was used as the dressing station and all protective clothing was stowed there before the trial commenced.

4. The C.P.O.M.(E) was in charge of the watchkeeping organisation. The time a watchkeeper left the citadel was entered on a board, and each man's relief was sent out at the appropriate time. Readings of personal dosimeters were entered on another board when each man left and returned.

5. The relieving man, using a hand bellows and carrying his respirator, passed out of the citadel through the P.O.'s bathroom (used as the monitoring and decontamination station) which functioned as an air lock for the citadel. Watchkeepers relieved on the plates, exchanging hand bellows and air hoses.

6. The fresh water showers provided at the access hatches to A Engine Room and B Boiler Room were not used, as the watchkeepers were thoroughly sprayed by the prewetting water, and, furthermore, delays in entering machinery spaces were undesirable, and the difficulty of operating the showers when using hand bellows was a cause of such a delay.

7. The man coming off watch passed first to the undressing station rigged outside the starboard passage screen door. Here the engineering undressing party, of two men dressed in 'Hurricane' rig, removed the ventilated suit and boots as rapidly as possible, and the man put on his own respirator as soon as his head emerged. Suit, boots and his respirator haversack were placed in bins, and the man was admitted to the monitoring and cleansing station after a code of knocks on the outer door had ensured that the inner door was shut. The man was then monitored, had a shower, and proceeded through the inner door into the citadel. The hand bellows he brought with him was monitored and decontaminated by washing, if required, before being handed into the citadel for use by the next series of reliefs.

8. A similar system was used by the ventilation parties entering or leaving, and by the watchkeepers in U.K.A.E.A. or 'Hurricane' suits. No suits of any description were worn twice, due to the risk of contamination, and their condition from the heavy perspiration of wearers.

SECTION IV - ENGINEERING

C. - FINAL ORGANISATION FOR WATCHKEEPERS (Continued)

Health Precautions

9. Each man was offered (and took) a drink of cooled lime juice and several salt tablets both before and after his watch. He was also instructed to pass water before his watch if possible.

10. No man with skin wounds or infections was dressed in any of the protective suits.

Other Precautions

11. The ventilation party were continuously at short notice for opening up ventilation in emergency, as were the first watch in U.K.A.E.A. suits.

12. Communication, though extremely difficult in the ventilated suits was just possible by means of an extension to the machinery intercom rigged in A boiler room cross passage inside the forward citadel. Watchkeepers wearing respirators were able to use all systems of communication, except when wearing either G.S. pattern respirators or Light Type without speech aids.

SECTION IV: - ENGINEERING

D. - MACHINERY COMPARTMENT VENTILATION

General.

For both trials the non-steaming machinery compartments, A Boiler Room and B Engine Room were completely shut down throughout, fans stopped and weather deck flaps shut and clipped. A Engine Room and B Boiler Room fans were stopped and weather deck flaps shut and clipped with the exception of the natural exhaust shutters specially fitted in both funnel uptake spaces. With the concurrence of the Health Physics Advisor these flaps were left open after trials had shown that :-

(a) In the steaming boiler room or where the boiler has only just been shut down, the heated air leaving the crown of the boiler room prevents the ingress of fall out; the airspace is itself a well shielded compartment. This would not apply in the case of a cold boiler room in which case the shutters would be shut.

(b) The time taken to restart the ventilation in an emergency or at the end of the closed down period is reduced.

(c) Some of the heat from the hottest part of the boiler room is removed.

2. The cover was placed in position on A Boiler.

3. The hatches and airlock doors (A Boiler Room) were shut on the non-steaming compartments but the former were left open in the steaming compartments. The doors of engine room and boiler room hatch lobbies were kept shut. The hatches were kept open to simplify the passage of men in ventilated suits, and being situated in the hottest parts of the compartments, this reduced the risk of delaying a man's departure through them. No fall out or prewetting water entered the compartments through these hatches although the danger of causing a depression in the boiler room was demonstrated when a blower-room door was left partly open during a practice, and prewetting was drawn inside.

4. Ventilation in the steaming compartments was restarted by a special ventilation party about 15 minutes before the end of the last 35 minute period watch in ventilated suits. The ventilation party, consisting of 1 P.O.M.(E) and 3, dressed in 'Hurricane' type suits, respirators, anti-flash hoods, oilskin hoods, gloves and rubber boots.

5. This party proceeded out of the forward citadel through the decontamination centre, opened B boiler room supply fan flaps and started the fans, the starters for which are inside the boiler room on the top grating, an extremely hot position. They then opened A engine room ~~after~~ forward supply and exhaust fan flaps and started these fans. (Note: All watchkeepers were warned to stand well clear of ventilation terminals while the fans were being started).

6. These fans were selected as having the most shielded weather deck openings - B boiler room air intakes are in the cross passage, and A engine room intakes are of the protected type, the air entering and leaving at the bottom. It was hoped that this procedure would avoid the risk of large scale contamination in the event of heavy fall out at the same time allowing sufficient active material to enter for trials evaluation.

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SECTION IV: - ENGINEERING

D. - MACHINERY COMPARTMENT VENTILATION (Continued)

7. The running of even this limited ventilation rapidly brought down the temperatures of the compartments, and watchkeepers in U.K.A.E.A. suits and respirators were able to relieve those in ventilated suits within 10 minutes of restarting ventilation, and to remain on watch with comparative ease for a period of 2¼ hours, or for longer periods if essential.

8. Some prewetting water entered the Engine Room through the ventilation supply trunking during both trials, and a little entered B boiler room through the supply trunking during FLASHLIGHT. No water entered either compartment through the exhaust trunking during either trial.

9. The ventilation party re-entered the forward citadel on completion of their task, passing through the undressing station, where they discarded their outer clothing and boots, and then through the monitoring and decontamination centre.

10. To ensure rapid opening in this case, the selected weather deck flaps were not hardened-down completely, and lines with loops were attached to the larger flaps to enable them to be temporarily secured in the open position, the securing clips fitted requiring extra time to be spent on the operation.

Note: A considerable time is required to harden-down all clips and wedges, particularly in view of the number of these fitted and the difficulty of maintaining them in an efficient condition.

(ii) Weather Deck Ventilation Flaps

Not all flaps in DIANA are fitted with wedge type clips, a number of the swing-bolt and butterfly nut pattern being still fitted. The latter require a considerable maintenance effort to keep serviceable. While the wedge type clips are preferred, the total numbers fitted are considerable, and the operation of closing down with the limited number of men available when the ship is preparing for State 1A takes much too long. This was emphasised during FLASHLIGHT, when fall out was reported to be arriving earlier than expected, and closing down became an evolution.

Examples of the number of clips fitted in DIANA are :-

A Engine Room - Forward supply and exhaust fans: 6 flaps each with 5 swing-bolt butterfly nut clips.

B Boiler Room - Two Supply fans: 4 flaps each, with 7 wedge clips and 1 swingbolt per flap.

The arrangement for holding the flaps open requires a man to climb above the flap to release the clip, with a similar climb on opening up again.

SECTION IV: - ENGINEERING

D. - MACHINERY COMPARTMENT VENTILATION (Continued)

(iii) Remaining Ventilation

The opening of the remaining ventilation in running machinery compartments and shut down compartments was co-ordinated with the ship's organisation for monitoring and decontaminating the upper deck. After the monitoring parties had made their report, the decontamination parties washed down the affected areas. They were instructed to wash down ventilation flaps and A boiler funnel cover as a primary task. Decontamination parties reported to A.D.C.D.H.Q. when all flaps and screen doors were cleared, and the ventilation party again left the citadel to open all remaining machinery space ventilation and lower the funnel cover on A boiler.

(Note): The funnel cover was put on when the boiler room ventilation was stopped. Hot gases continued to be produced, however, and vented through the vent hole fitted to all DARING class forward funnel covers. It would not have been possible to place a funnel cover over B boiler.

(iv) Conditions in Machinery Compartments

The conditions relating to both trials were approximately the same. Sea and ambient temperatures were somewhat lower for FLASHLIGHT but the effects of steam leakage were more noticeable to compensate.

2. It was hoped to reduce steam leaks to a minimum before the trials and to ensure dry bilges. In the event the Ship's Staff were unable to rectify a number of steam leaks, as it was impracticable to shut down owing to the necessity for running evaporators at Monte Bello. As a result, conditions were, though not ideal, probably more representative of the state in which a ship may frequently find herself.

3. Temperature and humidity records taken during the actual trials and during training exercises are shown in Appendices A, B. and C. It was found impracticable to take humidity readings with a whirling psychrometer, or even as many thermometer readings as planned. The necessary reduction of watchkeepers to 2 per compartment, and particularly the difficulty of reading instruments in distant places through the helmets of the IVC suits, were the principal reasons for this.

4. Apart from a possible contribution to the failure of a roller bearing plummer block, no defects or deterioration of equipment, mechanical or electrical, have been revealed. There has, however, been considerable rusting of exposed steelwork over the period of preparation and trials under humid and heated conditions, and deckhead paintwork appears to have deteriorated at an increased rate.

5. It was noticeable that in B Engine Room, which was shut down throughout the trials, and where although the main engines were stopped certain auxiliary machinery was in use, the highest temperature found in any machinery space during the trials were recorded at the manoeuvring position.

SECTION [illegible] - ENGINEERING

D. - MACHINERY COMPARTMENT VENTILATION (Continued)

(v) Recommendations

Ventilation Flaps - A great simplification of the securing devices is required. There should be not more than 3 large-handled clips, preferably quick-acting, per flap, and simple quick-acting arrangements for holding the flaps open, if only temporarily. These arrangements must be simple to operate in total darkness; it is noteworthy that during the trials under report full upper deck lighting was in use.

SECTION IV. - ENGINEERING

E. - OPERATION OF MACHINERY

(i) State of Machinery during HOTSHOT and FLASHLIGHT

B. Engine Room

Running machinery - Motor F/L Pump
Turbo fire and bilge pump
Main circulator
Motor extraction pump.

12" Vacuum was maintained in the condensor, it was found during early trials that it was necessary to maintain a level in the condensor and flow through the drain cooler to prevent the boiling of the main feed tank and the loss of suction by the auxiliary feed pump. Opportunity was taken to supplement the overflow tank during the trials by a man entering the engine room from the after citadel.

A Boiler Room - No machinery running

B Boiler Room - Auxiliary feed pump
Fuel oil pumps
H.P. Turbo Generator
Evaporator distilling to make up feed only
4 Turbo Blowers.

A Engine Room - All normal auxiliary machinery
Turbo fire and bilge pump

No. 1 Diesel Generator Turbine Turning Motor. - Running on load throughout both trials

Steam Leaks

HOTSHOT - A Engine Room - No significant leaks
B Boiler Room - auxiliary feed pump gland leaking badly.

FLASHLIGHT - A Engine Room - Fire extinguisher valve leaking badly
Centre pressure relief leaking on cross connection valve at manoeuvering platform
- B Boiler Room - Leak on master valve to auxiliary feed pump.

Bilges - 1" - 2" of water.

Conditions in both compartments, with the exception of the fire extinguisher leak in B Engine Room during FLASHLIGHT, were not abnormal.

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SECTION IV: - ENGINEERING

E. - OPERATION OF MACHINERY

(ii) Operation HOTSHOT

This trial was carried out with some difficulties due to shortage of feed water. Serious feed leakage outside the capacity of both evaporators developed shortly before the actual trials, and it was necessary to transfer some water from the ship's tanks to the feed tanks before the commencement of the trials in order to ensure a safe reserve of feed water during the shut down period. 8 tons of fresh water were transferred into 1 and 2 Reserve Feed Tanks. While it was desired to isolate these slightly contaminated tanks, it was in fact necessary to cross-connect Reserve Feed Ranks during the trials owing to difficulties in operating the feed system valves under shut down conditions. B Boiler feed supply as a result was below acceptable standards for a large proportion of the trials period, and recorded a salinity of 48 grains per gallon at the end of 13 hours' trial. B evaporators were run all this time and produced water of satisfactory purity, but only 21 tons of feed water remained by the end of the trials. Under these circumstances the forcing rate of the boiler was kept as low as possible, and speeds in excess of 14 knots were not exceeded; for the most time speeds were of the order of 10 knots.

2. Some manoeuvering was carried out, the principal difficulty experienced being communication between Engine Room and Boiler Room while wearing the air ventilated suits, and telegraph orders were not always distinguished immediately.

3. A Boiler Room and B Engine Room were shut down in plenty of time and the first watch in ventilated suits had taken over by the time of expected fall out.

4. Sequence of Events

Shut down A Boiler Room - 1205
Shut down B Engine Room and locked shaft - 1155
Shut down ventilation in A Engine Room and B Boiler Room - 1257
First watch below in ventilated suits - 1304
Ventilation party opened up ventilation - 1500 (to A Engine Room and B Boiler Room
First watch below in A.K.A.E.A. suits and respirators - 1515
All ventilation opened up - 2255

A Boiler Room and B Engine Room were re-entered, now wearing gauze masks and gloves, and A boiler flashed up connecting in place of B. A evaporators were run on make up feed.

5. Although it was possible to dispense with full protective clothing and respirators after the trials, monitoring of machinery compartments indicated contamination levels above the safety limits laid down. Gauze masks and anti-flash gloves were worn by all men in machinery compartments until such time as each compartment was declared clean by the health advisers.

6. Cleaning operations were carried out continuously to remove radioactivity: C.T.C. solvent was used and teepol and water on large surfaces. Details of contamination received, and methods of removal, are included in sub-section F.

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SECTION IV: - ENGINEERING

(ii) - OPERATION OF MACHINERY DURING HOTSHOT (Continued)

7. On return to Monte Bello early the following morning, orders were in force that evaporators were not to be used and both evaporators were then shut down.

8. B evaporator which was run throughout the trial was not allowed to distill to ship's tanks until 48 hours after permission was given to recommence evaporators. These limitations on the use of evaporators were the cause of a shortage of fresh water, and very strict rationing was imposed on passage back to Singapore. The lowest quantity used on one day was 9 tons for all ship's company.

(iii) Operation FLASHLIGHT

The time available for the ship to steam to the trials station necessitated a period of about 5 hours at 25 knots before shutting down A Boiler Room and the port shaft. On this occasion there were no machinery defects which would effect the trials operations. As in Hotshot there were a number of steam leaks which could not be remedied before the trials.

Significant leaks were :-

A Engine Room (a) Fire extinguisher valve leaking badly - not isolated as a result of hurried shut down.
(b) Main cross connection valve centre space pressure relief.

B Boiler Room (a) Auxiliary feed pump gland.
(b) Master valve to auxiliary feed pump cover joint.

2. The arrival of fall out in this exercise was earlier than anticipated and the shutting down of ventilation and manning the Engine Room and Boiler Room with the first watch in air ventilated suits was carried out as an evolution, and emphasised the deficiencies in ventilation flaps design and also difficulties of dressing in these suits in a hurry. The numbers of men available for shutting down ventilation are affected by the fact that at the same moment damage control state 1A is being implemented.

3. Sequence of Events

Shut down A Boiler Room - 1205
Shut down B Engine Room and locked Port shaft - 1229
Shut down ventilation in A Engine Room and B Boiler Room - 1232
First watch taken in air ventilated suits - 1250
"Fall out" party opened up ventilation - 1535 - to A Engine Room and B Boiler Room
First watch below in U.K.A.E.A. suits and respirators - 1545
All ventilation opened up - 2335.

4. During this trial, 174 R.P.M. were used giving a speed of 15½ knots, ~~minor limitations were not imposed as it was essential to position ship correctly as regards to fall out position.~~

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SECTION IV - ENGINEERING

E. - OPERATION OF MACHINERY DURING FLASHLIGHT (Continued)

5. Communication difficulties were the only problems when manoeuvering during the ventilated suit period.

6. B evaporator was run throughout, distilling to ~~ship's tanks~~ Reserve Feed Tanks. A evaporator was started up as soon as the boiler room was opened up. Although on this occasion the reserves of feed and fresh water remaining were adequate, there was again a restriction in the use of evaporators in the anchorage next day. B evaporators distilled to ship's tanks after 24 hours continuous distilling to make up feed in B Boiler Room Reserve Feed Tanks to obviate the use of main filling line.

7. Decontamination work required inside the machinery compartments was much less than in Hotshot, though minor inconveniences such as contamination of the syrens occurred.

8. Only seaweed and fish have been found in strainers and main condensers so no experience has been obtained from mud or sand deposits. Rubber gloves were always worn when cleaning strainers in the vicinity of Monte Bello.

9. The use of cloth overshoes after OPERATION FLASHLIGHT, undoubtedly prevented contamination being walked into otherwise clean compartments on the soles of men's boots.

(iv) Summary

While no risk was occasioned to machinery by the nature of these trials, due to continuous watchkeeping, the inability of watch-keepers keepers to carry out any rapid manoeuvering or to maintain full vigilance while in air ventilated suits was clearly shown. These difficulties are all capable of solution.

(v) Conclusions

As regards the radio-activity hazard, the most interesting revelation was the large amount of work, precautions and vigilance necessitated by the very small amounts of contamination received and distributed over small areas of machinery spaces. It appears evident that it is essential to keep ventilation shut during fall out and to prevent the entry of contamination on clothes or boots. The problem of evaporators was the most troublesome both at the time and afterwards. Whether or when a previously contaminated evaporator can be used on ship's tanks, the use of sections of filling line common with fresh water tanks were all questions requiring immediate decision which were extremely difficult to answer. The recommendations included in the trials section of this report are considered most important.

2. The fitting of separate feed water and fresh water filling lines from the evaporators would remove the difficulties which arise from a common line and limitations on the evaporators and tanks which may be used.

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SECTION IV: - ENGINEERING

F. - MACHINERY SPACES - RADIOLOGICAL TRIALS, MONITORING AND DECONTAMINATION

Arrangements were made for the following records to be taken, or tests made, during the period of fall out:-

(a) Dose rates in all parts of the machinery spaces in use, particularly in the vicinity of machinery which might become heavily contaminated.
(b) Transit doses in positions normally occupied more or less continuously by watchkeepers.
(c) Personal doses of all personnel occupied at any time in the machinery spaces. These were measured both by Quartz Fibre Dosimeters, for immediate reading of dose, and by film badges, for health control.
(d) Air contamination at the supply and exhaust ventilation terminals, and in the body of the compartments, during the time ventilation was open.
(e) Sea water sampling at intervals through the whole period, to provide for possible failure of the Scientific (A.R.L.) Party's sampling equipment.
(f) Sampling of the water made by the evaporator, at intervals during the time when it was considered by the Scientific Party that contamination at the appropriate depth (8 feet) was a maximum.
(g) Air sampling from the neighbourhood of the cylinder heads of No. 1 Diesel Generator, for comparison with other air samples in the forward citadel.

2. Other arrangements made, for tests and evaluation later, were as follows :-

(a) Continuous sampling of the intake air and funnel gas of B Boiler for comparison with a similar sample from the unprewetted part of the forecastle. Samples of soot were also taken later.
(b) 94 steel plates were sited throughout the combustion air/gas path of B boiler, to find the relative magnitude of fall out deposits at various points. 6 sample bricks were sited in the furnaces.
(c) A number of steel plates were sited near the cylinder head of No. 1 diesel generator, to find whether any active material escaped through gas or oil leaks.
(d) On the next occasion of blowing down evaporators, samples of scale from each were taken and examined.
(e) On each occasion thereafter of opening up any part of the sea-water systems (e.g. condensers, pump strainers) the contents were monitored, and if contamination appeared significant, samples were taken for closer examination.
(f) A careful monitoring survey of all machinery spaces was made immediately after clearing fall out. This served the dual purpose of guiding decontamination work and providing trials records.

3. The results of the 'immediate' records and tests may be summarised as follows :-

SECTION IV: - ENGINEERING

F. - RECORDS ETC. (Continued)

(a) Dose Rates, Transit Doses and Personal Doses recorded were all negligible. This was confirmed by monitoring after clearing fall outs, which indicated dose rates of about 0.2 to 0.4 mR/hr. generally in the machinery spaces, rising to 4 mR/hr. in areas directly exposed to the ventilation inlets. The use of polythene bags for dose-rate meters was found to be impracticable.

(b) Air contamination in the ventilated spaces never rose to a high level, but was sufficient to indicate that of the contamination entering the space, not more than 50% at the most was taken away in the exhaust air. Lack of power supply prevented sampling at the upper deck terminals.

(c) Sea water samples were taken, but were not required by the Scientific Party.

(d) Evaporator distillate samples were also taken, but the Scientific Party later stated that there was no means of evaluating them.

(e) Air samples from the diesel generator showed negligible contamination.

4. Examination of the boiler intake and uptake samples showed that a considerable amount of activity entered the system, but that virtually none emerged from the funnel. The amount retained on the detector plates did not justify removing all the plates from the boiler casings, but examination of a representative selection of these, plus all the plates from the intakes and blower rooms, yielded sufficient information to justify detailed evaluation. Some of the data required for this work is not available on board, but a preliminary survey of the results leads to the following tentative indications :-

(a) That of the contamination entering, very little was wet (i.e. carried by prewetting) and only a very small proportion emerged from the funnel.

(b) That a large proportion of the contamination was deposited in the intake trunking and on comparatively limited surfaces in the blower rooms.

(c) That of the contamination passing the blowers, the majority was deposited either in those parts of the casing where the airstream curves, on, or rather in, the brickwork, or in the lighter soot (i.e. that carried up to the tubes and economiser, not that deposited around the burners).

5. The effect of sootblowing could not be assessed, as for operational reasons the boiler could not be used between the end of the trial and the ship's arrival in Singapore.

6. Examination of the scale from the evaporators showed, as would be expected, contamination in the shell which had been in use during fall out, but the inability to assess either the feed or the distillate samples makes it unlikely that any further conclusions can be drawn from this trial alone. The effect of blowing down on scale activity could not be assessed, as water activity was present at intervals for some time after the trial, and the activity in the scale was very patchy.

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SECTION IV - ENGINEERING

F. - RECORDS ETC. (Continued)

7. Examination of deposits in seawater inlets was also inconclusive. Activity was present, but as much of the seaweed around the islands was itself active, not only in the trial area, and as no deposits other than weed and fish were found, no useful results could be obtained.

8. Monitoring in the machinery spaces was mainly a matter of searching for loose contamination by taking smear tests on filter paper and counting the papers in a standard lead castle. These tests showed that initially the levels of loose contamination were well above the health tolerance throughout both the machinery spaces in use. Particularly high spots were found at any position directly in front of ventilation terminals, and all over decks. By these tests, lagging did not appear to be very much more contaminated than other surfaces in similar positions, but this cannot be considered reliable evidence, as it was not possible to include in a smear test the probable release of loose contamination occasioned by, for example, shaking the lagging, and overall levels were not sufficient to enable reliable results to be obtained with the portable ratemeters available.

(ii) Monitoring and Decontamination - HOTSHOT

9. As soon as it was clear that the ship was not re-entering the fall-out, a further set of air samples was taken for health physics clearance in each machinery space in use, and when these had been examined, monitoring, as described above, was started. The results of the first survey showing, as above (8), levels of loose contamination far above tolerance, it was not at once possible to allow watchkeepers to remove their protective clothing. It was decided therefore that surgical gauze masks and gloves were to be worn by all men in the machinery spaces, and that boots worn by them were to be removed before entering the citadels.

10. As soon as possible, decontamination of all spaces was started. it had been found on the initial survey that both the spaces not in use during fall out had some contamination on their deckplates and ladder treads due to carry-over on boots and shoes while opening up after the trial. All deck plates and ladder treads in these spaces were washed down with rags soaked in C.T.C. (the only suitable solvent available, as fresh water was very short and the seawater in the neighbourhood was reported to be contaminated). It was found that traffic from the upper deck, which by then had been opened to general use, brought in as much contamination as was removed, but by that time decay had reduced the activity, to the extent that the use of protective clothing in these two spaces was discontinued at H + 28 hours (1600 on 17th May).

11. Attention was then turned to the two more heavily contaminated spaces. The same methods were used, except that the washing was extended to all surfaces likely to be touched, rubbed against or trodden on in the normal course of events. It was soon found that in the same way as in the other two spaces, carry-over on boots and shoes from the upper deck nullified all attempts to decontaminate deck plates and ladder treads, but as the ingestion hazard from deck plates was considered small, restrictions on men performing normal watchkeeping duties (i.e. not working on lagging, entering the boiler casings etc.) were removed, for A engine room at H + 48 hours (1200 on 18th May) and for B boiler room at H + 72 hours (1200 on 19th May). By this time also, seawater could be

SECTION IV: - ENGINEERING

F. - RECORDS ETC. (Continued)

used for cleaning, and the intake trunks to the blower rooms had been washed down with that. The accessible parts of the blower rooms were treated in the same way as the machinery spaces themselves.

12. Inaccessible parts of the machinery spaces, and the air casings of B boiler were left to decay naturally, such work as removing the detector plates and bricks from the boiler being carried out in protective clothing. Restrictions were finally removed from the machinery spaces on 22nd May, and from the boiler on 8th June.

(iii) Miscellaneous Precautions.-HOTSHOT

13. Monitoring of pump strainers on return to the anchorage confirmed reports that seaweed in the vicinity of the islands was mildly active. All cleaning and changing of strainers was therefore carried out wearing rubber gloves, and avoiding all direct contact with the weed, until some time after leaving the area.

14. For some considerable time after the event, neither evaporator could be used for making drinking water, since B evaporator was slightly contaminated, and in any case, as the seawater in the anchorage was reported to be slightly active, orders from the Operation Health Physics Controller forbade distilling for any purpose. At H + 27 hours (1500 on 17th May) permission was obtained to distil for feed water, and this was quickly followed by the removal of all restrictions on distilling (apart, of course, from the contaminated shell of B evaporator). The portion of the distilling line which might have been contaminated from this evaporator during fall out had already been drained, and the shell was kept distilling to feed, thus flushing through the system, until H + 77 hours (1700 on 19th May) when it was considered by the Health Physics Adviser on board to be safe to distil for any purpose.

(iv) Trials - FLASHLIGHT

15. In general, the arrangements for trials were similar to those for the first weapon (1 and 2 above). There were, however, one or two differences, mainly of detail, as follows :-

(a) Additional power supplies were arranged for air sampling at the upper deck ventilation terminals (supply and exhaust) of A Engine Room.

(b) The arrangements for more or less continuous [illegible] sampling were discarded as unnecessary.

(c) The sampling from the evaporator was arranged to be one very large sample from seawater, and one from distillate, at a time to be selected by the Scientific Party. Owing to the size of the sample required, it was not possible to arrange for a series.

(d) As only a selection of the detector plates had been removed from B boiler after the first test, more were available for the second, and a considerably increased number were sited in the blower rooms and intakes, where it was reasonably certain that contamination would be heaviest, bringing the total number of plates in the system to 120, of which 48 were in the blower rooms and intakes, with, in addition, 11 sample bricks in the furnaces.

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F. - RECORDS, ETC. (Continued)

(e) Four small pieces of asbestos cloth were strapped to lagging in the blower rooms of B boiler.
(f) Twenty four of the steel plates, and eight pieces of asbestos cloth were distributed about A Engine Room.

16. The results of the 'immediate' records and tests may be summarized as follows :-

(a) Dose Rates, Transit Doses and Personal Doses were all negligible.
(b) Air contamination in the machinery spaces appeared to be nil, no fall out having apparently been met after machinery space ventilation was opened up. (This was later confirmed by monitoring, and by examination of the plates and lagging samples from the Engine Room.
(c) Seawater contamination never rose to a level at which the Scientific Party considered it possible to evaluate samples, particularly of evaporator distillate, and therefore none were taken.
(d) Air samples from the diesel generator showed no contamination.

17. Examination of the boiler intake and uptake samples showed only a very small amount of contamination at the intake, and none in the uptake. This was surprising, as the upper deck contamination appeared somewhat heavier than in the first test. That the boiler contamination might be somewhat lower than in the first test was indicated by the detector plates in the blower rooms, but not to the extent suggested by the intake sample. It appears possible that particle size, for instance, may have affected the results, or that the samples were not operating correctly during the critical period. Further analysis is required before a solution can be reasonably suggested.

18. Examination of the plates and samples removed from the blower rooms showed a similar pattern of contamination to that obtained in the first test, but on a lesser scale. Removal of the samples from the boiler itself was not possible, for operational reasons, for a considerable time after the event. This was unfortunate, particularly in view of the low level of contamination. The samples were removed on 2nd July, and examination showed an apparently similar contamination pattern to that found after HOTSHOT, but on a so much lesser scale that the immediate impression could not be considered very reliable. Brick dust from the furnace showed slight contamination by α emitters, and it was necessary to order continued use of protective clothing and respirators for work in the boiler involving disturbance to brickwork.

19. The effect of sootblowing could not be assessed, since for operational reasons it was necessary to keep steam in B boiler until arrival in Singapore, and therefore to blow soot on the way. Even had this not been necessary, it is in fact doubtful whether any definite conclusions could have been drawn owing to the low level of initial contamination.

SECTION IV - ENGINEERING

F. - RECORDS ETC. (Continued)

20. Samples of evaporator scale again showed slight activity, but it was too unevenly distributed to enable the effects of blowing down to be assessed, particularly as it was suspected that some seawater contamination had been encountered after the first blow-down following the event.

21. The air filter on the diesel generator showed no appreciable activity to a portable meter. This was not surprising, as the intake trunking is long and devious, and the intake well shrouded.

22. The Porton filters on the ventilated suit supply systems likewise showed very little activity, insufficient to provide any useful information.

23. A sample of lubricating oil from the diesel generator was examined by the Scientific Party, and was stated to show insignificant activity.

24. The [illegible] plates around the cylinder heads of the diesel generator show [illegible] activity.

25. [illegible]itoring in the machinery spaces was, as before, mainly a matter [illegible] searching for loose activity, though confirmation of the result [illegible]as later obtained by examining the plates and samples from A e[illegible] room. Surveys with dose-rate meters showed readings of in[illegible]gnificant magnitude. Smears from all machinery spaces were [illegible]mined, and the only contamination found was a very little on the footplates of A engine room and B boiler room. It was therefore clear that no fall out had entered the machinery spaces through the ventilation, though, as was to be expected, some had been transferred from the upper deck on the soles of boots. This was later confirmed by examination of the plates and samples from A Engine room.

(v) Monitoring and Decontamination - Flashlight

26. As reported above (25), the first monitoring survey showed that very little contamination had entered the machinery spaces. Accordingly, A boiler room, A Engine room and B engine room were declared 'clean' at once (0130, 20th June). The wearing of overshoes while on the upper deck by men proceeding to and from the machinery spaces was found to be a satisfactory method of preventing these spaces from contamination by carry-over on boots and shoes from the upper deck. B boiler room deck plates were over tolerance for loose contamination, almost certainly due to transfer on boots during the closed down period. Gauze masks, gloves and overshoes were prescribed for wear here until cleansing could be completed, and in order to prevent transfer from the still relatively heavily contaminated upper deck, the overshoes used in the boiler room were kept separate from those worn on the upper deck in transit to and from the citadels.

27. The next day (20th June), all deck plates and ladder treads in B boiler room were cleaned with solvent, as before, and further smear tests taken to check the decontamination. A set of smears was also taken from the blower rooms to check the decontamination necessary. At H + 34 hours (2000 on 20th June) the boiler room was declared 'clean'. At the same time, surprisingly, it was found possible to discontinue the use of protective clothing in the blower rooms for ordinary work, that [illegible] other

SECTION IV - ENGINEERING

F. - RECORDS ETC. (Continued)

then crawling over the blowers, working on lagging, or working in the intake trunkings. It was considered that what activity remained would decay sufficiently rapidly to make this restriction reasonable.

28. At the same time, the problems of access to and cleaning the syrens was considered. As the syrens and the ladders and platforms immediately below them had not been prewetted, it was decided to leave them to decay and weather for as long as possible. Smear tests were taken on 26th June (H + 7 days) and showed loose contamination still well above tolerance (about ten times). The bellmouths were cleaned on 27th June by men wearing gloves, gauze masks and overshoes.

29. The casings etc. of B boiler were, as before, left to decay naturally, the work of removing plates and samples from the boiler being carried out in protective clothing. Unfortunately, owing to the ship's programme and the failure of the after plummer block on the starboard shaft, it was not possible to enter the boiler until after arrival in Singapore.

(vi) Miscellaneous Precautions - Flashlight

30. As after the first test, monitoring of pump strainers and the use of rubber gloves for changing or cleaning them, was continued until after leaving the vicinity of Monte Bello.

31. Use of A evaporator was not restricted after the test except for a short period in the anchorage during which no distilling for any purpose was permitted. B evaporator, which had been slightly contaminated during the test, was kept distilling for feed water, except for the short period referred to above, until H + 46 hours (0800 on 21st June) by which time examination of the scale from blowing down showed negligible activity. It was then considered by the Health Physics Adviser on board to be safe to distil for any purpose.

(vii) Interim Conclusions - Whole Trial

32. Although it is not possible without further analysis to draw detailed conclusions from the results of the trials carried out as such, certain general points stand out at once. These are :-

(a) That dry fall out can and will enter ventilation systems, even if the intakes are in relatively sheltered positions, in spite of prewetting, and although a large proportion is likely to be deposited in the entry trunking, it can pass a number of bends in at least sufficient quantity to be a major nuisance. (The particles entering DIANA's engine room had to describe two 180 degree bends before even reaching the fan.)

(b) That of the particles entering any system, the great majority will be deposited throughout the system, and not exhausted with the air.

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SECTION IV - ENGINEERING

F. - RECORDS ETC. (Continued)

(c) That if the internal hazard safety rules applied during these operations are at all related to those which would be applied in wartime, it is essential to avoid any need for unfiltered external ventilation, or opening of doors or hatches, in machinery spaces during fall out, as the interference with normal operation, combined with the complications of monitoring and the need for additional stores, caused by even a minute amount of contamination is great, and may therefore be expected to be quite unacceptable in the event of even light to moderate fall out.

(d) That three further Radiac instruments are required to complete the Service range, viz:-

(i) A survey meter to bridge the range of dose-rate between the Contamination Meter (0-10mR/Hr.) and the lowest range of the present Survey Meter No. 2 (0-3R/H.). It is suggested that the Meter, Survey, Radiac No. 3, 6665-110121, is basically ideal for the purpose.

(ii) A portable meter for assessing fixed and loose contamination of surfaces, irrespective of gamma background, with particular reference to the internal hazard safety limits to be applied in wartime.

(iii) A meter for measuring fresh water contamination to the extent required by the safety limits to be appli[illegible] to drinking water in wartime. (The Contamination Meter No. 1 with liquid counter appears, by the standards of this operation, to be much too insensitive for this purpose.

(e) That the polythene bags supplied for service dose-rate meters are insufficiently transparent for use in difficult conditions such as in machinery spaces when wearing respirators.

(f) That further trials, to ascertain with reasonable accuracy the extent to which ship's evaporator's output may be contaminated from a known feed contamination, are of the highest importance.

(g) That there is, at first sight, an encouraging impression of likeness between the results of the trials carried out in B boiler and the results of the trial carried out with sprayed chemical tracer in H.M.S. DECOY, in spite of the fact that in the trials here reported the contaminant was not waterborne. Much remains to be done, however, before this impression can be confirmed or otherwise.

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SECTION IV: - ENGINEERING

G. - PERSONNEL

The department co-operated cheerfully and well in helping to develop these new methods of steaming the ship under trials conditions. When the ship left Devonport with much odd equipment on board, and the ship and machinery new and strange to almost everyone, the actual task to be undertaken had not been disclosed to the Ship's Company; not until the ship had left Singapore was the full story known.

2. No cases of incapacity arose as a result of the trials conditions, although, especially in the early stages before the optimum periods of watches had been established, a number of cases of near heat exhaustion were reached.

3. Interest was notably on the effects of radiation on people, and as was to be expected many of the more alarming theories current in the press were discussed. It was of interest to note that while the trials were in progress and at least the threat of fall out was present, precautions were properly taken. After the trials were over however, there was a noticeable tendency among some men to relax and assume a more casual attitude towards the health rules still in force. This was despite a number of lectures on board before the trials. This attitude was improved before the second trial but it did emphasise the importance of this aspect of training.

APPENDIX A

Engine Room Closing Down Trials - Temperature Records - Engine Powers various, but never over 25% Full Power.

TABLE 1.
24th April

Sea Water 84° F, Upper Deck Air 83° F, Dry Bulb 71° F, Wet Bulb - Relative humidity 53%.

Time	Temperatures etc. Starting Platform °F Dry Bulb	Inside Ventilated Suit Dry Bulb °F.	Inside Ventilated Suit Wet Bulb °F	Remarks incl. Rel. Humidity in suit
1015	100	99	84	R.H. 53%
1025	118	106	88	Closed down 1020 R.H. 48%
1035	122	110	92	R.H. 49%
1045	127	109	92	R.H. 49%
1055	130	108	93	R.H. 56%
1100	132	109	94	R.H. 56%
1105	125	-	-	Vents open 1101

TABLE 2.
1st May

Sea Water 82°F, Upper Deck Air 87°F, Dry Bulb, 79° Wet Bulb, Relative Humidity 69%

Time	Temperatures etc. Starting Platform D.B. °F.	Starting Platform W.B. °F.	Starting Platform R.H. %.	In Ventilated Suit D.B. °F.	In Ventilated Suit W.B. °F.	In Ventilated Suit R.H. %	Remark
1330	102	89	59	97	88	69	
1350	112	102	67	102	91	65	Closed down 1340
1400	123	107	58	109	93	54	
1410	127	111	59	109	95	59	
1420	129	113	60	109	95	59	
1430	129	113	60	112	94	50	Endurance limit in suit
1440	130	113	57				
1450	132	114	56				
1500	134	114	52				
1510	134	114	52				
1520	135	115	53	112	90	41	Fresh man in suit
1530	135	115	53	112	90	41	
1540	135	115	53	112	93	48	

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SECTION IV: - ENGINEERING

APPENDIX A (Continued)

TABLE 3
5th May

Rehearsal for HOTSHOT

Seawater 84°F. Upper Deck Air 78°F., D.B. 70°F, W.B. Rel. Humid- 66%.

Time	Starting Platform D.B. °F	Starting Platform W.B. °F	Starting Platform R.H.%	Compt. Crown D.B. °F	In Ventilated Suit D.B. °F	In Ventilated Suit W.B. °F	In Ventilated Suit RH %	Remarks
1550	111	97	59	128	100	84	50	Vent. Shut Down
[illegible]	119	105	62	130	113	88	36	
1610	[illegible]	109	63	132	112	89	39	
1620	127	111	59	140	112	90	41	
1630	129	114	62	142	118	90	32	
1640	133	116	58	143	-	-	-	
1650	133	116	58	145	107	90	51	New main in suit
1700	134	118	61	147	122	91	[illegible]	
[illegible]	136	119	60	149	121	91	31	
1720	136	119	60	149	-	-	-	
1730	134	119	[illegible]	150	-	-	-	
1740	135	120	63	150	-	-	-	
1750	103	90	60	110	-	-	-	½ vents opened 1745

TABLE 4
16th May

OPERATION HOTSHOT

Seawater 79°F. Upper Deck Air 75°F Dry Bulb, 67°F Wet Bulb
Relative Humidity - 65%

Time	Starting Platform Conditions D.B. °F.	W.B. °F.	R.H.%	Remarks
1230	99	83	50	Vents closed 1304
1315	120	102	53	
1345	131	113	55	
1430	132	114	55	
1500	132	113	55	Vents open 1500

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SECTION IV. - ENGINEERING

APPENDIX A (Continued)

TABLE 5
1?th June

OPERATION FLASHLIGHT

Seawater 77°F. Upper Deck air 67°F Dry Bulb
61°F Wet Bulb
Relative Humidity - 70%

Time	Starting Platform Conditions D.B. °F.	W.B. °F.	R.H.%	Remarks
1245	98	82	49	Vent. closed down 1250
1300	117	101	56	
1315	124	108	58	
1330	130	112	55	
1345	132	115	58	
1400	133	116	58	
1415	134	117	58	
1430	133	115	57	Vents remained closed until 1530

SECTION IV: - ENGINEERING

APPENDIX B

BOILER ROOM CLOSING DOWN TRIALS - TEMPERATURE RECORDS

Engine Powers various, but never over 25% Full Power

TABLE 1
25th April

Seawater 84°F. Upper Deck Air 81°F Dry Bulb
71°F Wet Bulb
Relative Humidity 60%

Time..	Control Pos. D.B.°F	Control Pos. W.B.°F	Control Pos. R.H.%	Upper Grating D.B.°F	In Vent. Suits D.B.°F	In Vent. Suits W.B.°F	In Vent. Suits R.H.%	A/C disch. D.B.°F	Remarks
1020	99	92	76	115	89	87	92	134	
1035	101	95	80	120	94	89	82	142	Closed down 1032
1050	115	110	84	160+	102	97	83	146	
1100	111	102	[illegible]	160+	100	94	79	150	Opened up 1058
1110	109	93	54	150	96	93	89	143	

Note: - Trial was abandoned at 1058, as excessive temperature at upper levels made it doubtful whether ventilation party could reach fan starters in event of an emergency.

TABLE 2
5th May

Rehearsal for [illegible]

Seawater 84°F. Upper Deck Air 78° Dry Bulb
70° Wet Bulb
Relative Humidity 66%

Time	Control Pos. D.B.°F	Control Pos. W.B.°F	Control Pos. R.H.%	By T/G D.B.°F	By Evap. D.B.°F	In Vent. Suits D.B.°F	In Vent. Suits W.B.°F	In Vent. Suits R.H.%	Remarks
1550	99	90	70	100	101	-	-	-	Closed Down 1550
1600	110	95	56	111	109	-	-	-	
1610	114	99	58	118	113	-	-	-	
1620	117	103	61	124	119	-	-	-	
1630	12[illegible]	107	62	126	124	-	-	-	
1640	124	110	63	128	127	-	-	-	
1650	12[illegible]	112	68	132	128	-	-	-	
1700	126	114	68	134	129	105	91	58	
1710	128	115	66	135	130	105	92	60	
1720	128	115	66	134	132	107	93	58	
1730	130	117	66	134	132	108	94	58	
1740	130	118	69	134	134	109	93	54	Opened vents 1740

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SECTION IV: - ENGINEERING

APPENDIX B (Continued)

TABLE 3
16th May

OPERATION HOTSHOT

Seawater 79° F. Upper Deck Air 75° F Dry Bulb
67° F Wet Bulb
Relative Humidity - 65%

Time	Control Position Conditions D.B. °F.	W.B. °F.	R.H.%	Remarks
1300	98	81	46	Closed Down 1304
1315	111	93	51	
1345	120	102	53	
1415	122	104	55	
1445	121	105	54	Vents opened 1500

TABLE 4
19th June

OPERATION FLASHLIGHT

Seawater 77°F. Upper Deck Air 67°F Dry Bulb
61°F Wet Bulb
Relative Humidity - 70%

Time	Control Position Conditions D.B. °F.	W.B. °F.	R.H.%	Remarks
1245	105	87	48	Vents closed down 1250
1300	121	102	51	
1330	127	108	52	
1400	130	111	53	
1445	129	112	56	Vents remained closed until 1530.

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SECTION IV: - ENGINEERING

APPENDIX C

MAXIMUM TEMPERATURES

Comparison of maximum temperatures at various positions during closed down periods of HOTSHOT and FLASHLIGHT with normal operating conditions.

Compartment (and time closed down)	Position	Max. Temps. HOTSHOT °F	Max. Temps. FLASHLIGHT °F	Normal Temp. °F
A Boiler Room (11 hours)	Control Position	134	148	95
A Engine Room (2 hours)	Starting Platform	132	134	98
	Adj. to scoop inlet	98	100	82
	Ford. end, H.P. Turbine	144	154	102
	Entry Hatch	138	144	98
B Boiler Room (2 hours)	Control Position	122	130	101
	By Turbogenerator	128	131	96
	By Evaporator	123	135	103
	Escape Hatch	160+	160+	125
B Engine Room (11 hours)	Starting Platform	158	160+	103

SECTION IV: - ENGINEERING

APPENDIX D

Northey Compressors for Ventilated Suits - Operating Conditions

Manufacturers' Data

Compressor - Twin-barrel type 1632 C.W.D.
R.P.M. - 1750
Max. Circ. water Disch. Temp. 30°F

Disch. press. p.s.i.g.	5	10	20
Output cu. ft. per min.	85	82	75
Power used, H.P.	7.5	9.0	12.0

Motor - Brooke Motors Ltd. Type R.13
440 volt, 3-phase, 60 c.p.s.
R.P.M. - 1740
Maximum continuous output - 10 h.p.
Maximum continuous phase current - 12.5 amps.

2. **Operating Conditions - Motors**

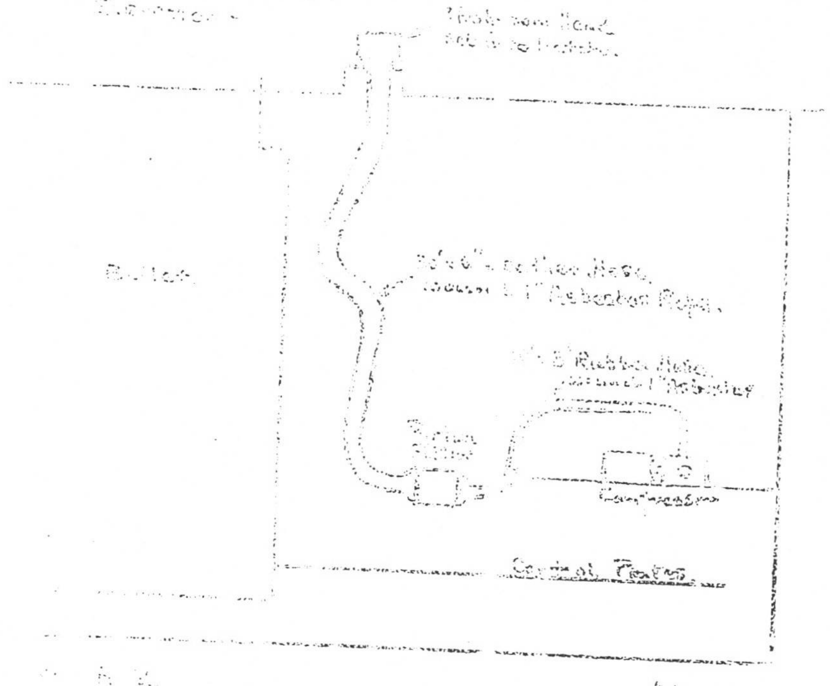
All tests carried out with circulating water inlet temp. 80°F
outlet 87°F

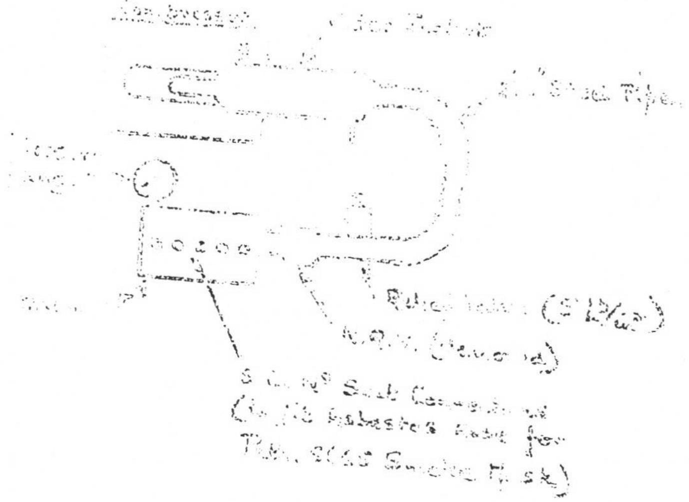
Air Discharge Conditions	Disch. Press. p.s.i.g.	Motor Phase Current Amps Engine Room	Boiler Room
To fixed pipe and hoses	2	16.5	15.5
To fixed piping only	1	14.0	13.5
Disconnected at compressor flange	-	13.0	12.0

3. **Operating Conditions - Compressors**

	As originally fitted		After fitting Air Cooler		With air cooler and lagged inlet	
	E.R.	B.R.	E.R.	B.R.	E.R.	B.R.
Sea Temperature, °F	84	84	85	85	85	85
U.D. Air Temperature °F	81	81	83	83	83	83
Compartment Temperature °F	105	110	105	100	105	105
Air Manifold Temperature °F	148	150	125	129	129	130
Air temp. at end of hose °F	-	-	107	108	109	110
Air discharge Press. p.s.i.g.	2	1½	2	1½	2	1½

'B' Boiler Room





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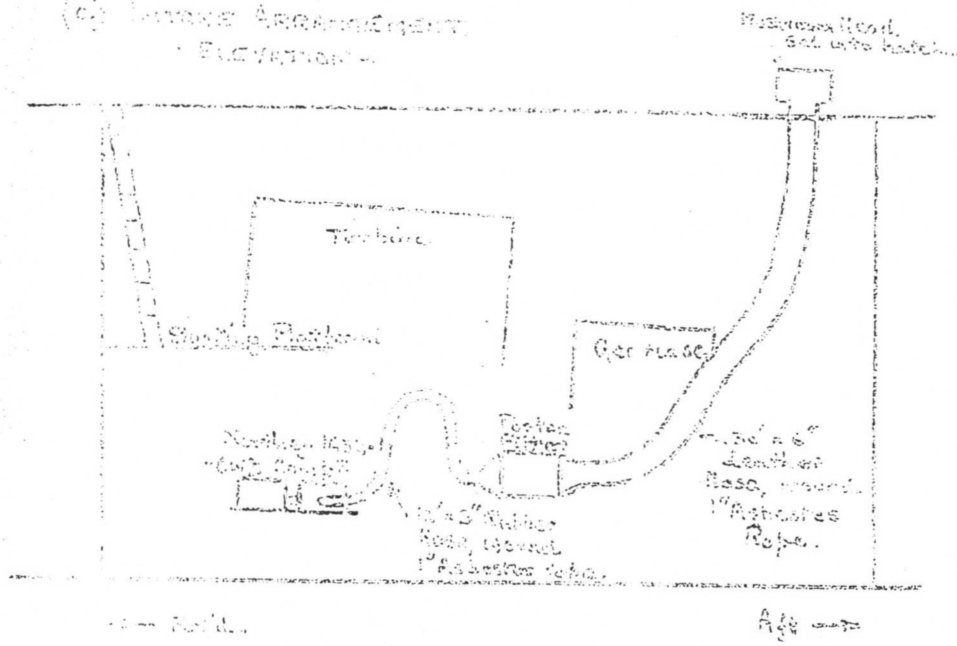
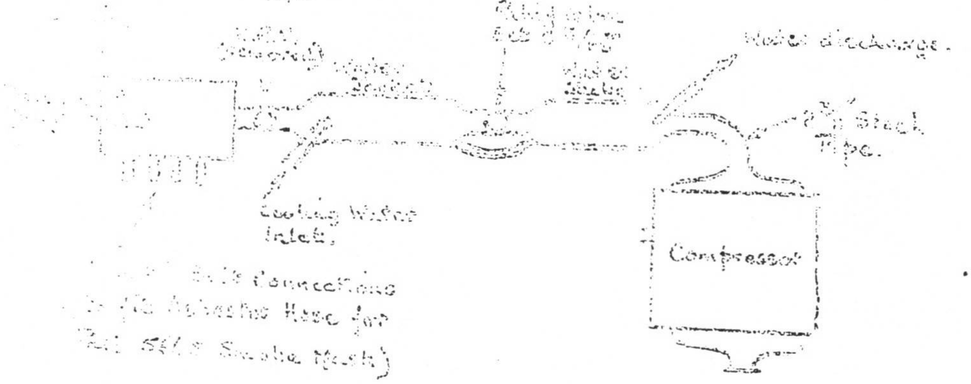
U.K. [illegible]

'A' Engine Room.

(c) [illegible] Arrangement
- Elevation -



[illegible] Arrangement
- Plan -



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H.M.S. DIANA'S REPORT ON OPERATION MOSAIC

SECTION V - ELECTRICAL

(i) Supply and Distribution

The steaming unit during the whole of Operation 'MOSAIC' consisted of "A" Engine Room and "B" Boiler Room. "A" Boiler Room and "B" Engine Room were unmanned, therefore the only sources of power available were turbo generator M.4 and diesel generators H.1 and K.3.

2. M.4 turbo generator supplied P.4, H.2 and H.3 switchboard sections. H.1 diesel generator supplied P.5 and H.1 switchboard sections. All interconnecting switches were closed. Bus-bar linking switches P4/centre section /P5 and H3/H1 were open. Bus-bar linking switch H.2/H.3 was closed. K3 diesel generator was available as standby generator but not running.

(ii) Important Services

(a) Steering motors - Starboard supplied from H.1-02.
Port supplied from P.4-07.

(b) Forced lubricating pumps - "B" Engine Room P4-11(N), H1-07(A)
"A" Engine Room H2-07(N), P5-04(A)

(c) L.P. Services forward. It was found necessary to supply the control and communication switchboard machinery from the alternative supply H2-01, since the capacity of the diesel generator was insufficient to provide a suitable reserve of power. To change over from alternative supply to normal supply, P5-05, should M4 generator have failed would have taken a few seconds, since these auto change over switches are not fitted with homing relays. The risk was considered acceptable.

(iii) Turbo-Turning Motors

During both Mosaic Operations the turbo turning motor in "B" Engine Room was running continuously, i.e. approximately 12 hours in each case. No signs of strain or overheating were observed.

(iv) 10 H.P. Compressor Motors

10 H.P. compressor motors for the ventilated suits in "A" Engine Room and "B" Boiler Room. A separate report has been written elsewhere about the compressor, but electrically these machines were satisfactory. As a safety precaution the thermal overload device in the starters was gagged, since it was thought that the high ambient temperatures might possibly trip the starter at a moment embarrassing to the ventilated suit wearer.

(v) Machinery in "A" Engine Room and "B" Boiler Room.

Ambient temperatures are shown in Appendix C to Section IV and no trouble was experienced with electrical equipment under these conditions.

SECTION V - ELECTRICAL

(vi) Internal Communications

(a) Machinery Spaces. During the training of engine room staff in the use of ventilated suits, it was found that owing to the noise of rushing air inside the suits, the normal sound power telephones became practically useless. For this reason the machinery broadcast system was put to full use. In addition a microphone and quiet speaker were installed in the forward citadel adjacent to A.B.C.D H/Q, in the cross passage outside "A" Boiler Room hatch. This proved to be of value to the Engineer Officer in controlling his machinery spaces from above. The noise did not interfere unduly with personnel in A.B.C.D. H/Q. A Pattern 12608 speaker was found satisfactory for this purpose.

(b) Communications from inside the Citadel to Outside. Exclusive use of the Main and Armament Broadcast from A.B.C.D. H/Q was made throughout. This was satisfactory except for a number of blind spots on the upper deck. These were as follows:-

(a) On the Forecastle.
(b) "B" Gun Deck.
(c) "X" Gun Deck.
(d) Iron Deck - Port Side.

(c) Communications from Outside the Citadel to Inside the Citadel. This proved to be very poor. One automatic telephone at the quartermaster harbour position and the quarterdeck sound power phone connected by the Bridge T.C.B. to D.C.H/Q provide the total means of communication. Delays during monitoring and decontamination were caused through lack of good communications.

(d) Radio Link between Upper Deck and Forward Citadel. An attempt to improve communications was made by using Portable Control Units Design 6 plugged into the normal positions on the forecastle and quarterdeck. Communication was established between A.B.C.D. H/Q and these positions via the C.C.X. lower and upper boards on the Main Wireless Office, and a B.40 receiver alongside it. The B.40 was connected into the C.C.X lower and upper boards in the Main Wireless Office. Transmissions from the Type 618 were picked up by the B.40 and relayed via Control Outfit ^ to the A.B.C.D.H.Q. This scheme proved unsatisfactory due to a breakdown in the transmitter caused by overheating. Since the 2nd Wireless Office is a gas free compartment, it was closed down completely with no ventilation whatsoever, and the excessive heat generated caused overloading and the fuses to the modulator to blow. Type 602 Transmitter in the Main Wireless Office and a B.40 were subsequently rigged in a similar manner, and good results were obtained. This latter method is not recommended since, to prevent radiation from the transmitter aerial, it was necessary to de-tune the P.A stages and the aerial tuning unit. Even then, under wartime conditions, this would not be an acceptable risk. ^ (insert) K.H.C.

SECTION V - ELECTRICAL

(vii) Ventilation

(a) The task of closing down ventilation in the forward and after citadels was undertaken by the Electrical Repair Parties, while that of closing scuttles, doors and hatches was the responsibility of the Damage Control Parties.

(b) On assuming A.B.C.D. State 1A, ventilation feeder breakers were immediately opened, and ventilation task boards issued to the ventilation party. These task boards proved successful since they provided each rating with all the information he needed; viz. route to follow, the flaps to close, slide valves to close, recirculating flaps to open and the state in which the fans should be left. They also provided a check for the rating in charge in each citadel that all tasks had been completed when the boards had been returned. On completion of the ventilation tasks the ventilation feeder breakers were closed and all recirculating fans and air filtration units started. The following data on closing down is of interest.

Time to close down Forward Citadel	-	14 Minutes.
Time to close down After Citadel	-	10 Minutes.
Pressure obtained in Forward Citadel	-	$2\frac{1}{8}$ (G1) $1\frac{5}{8}$ (G2)
Pressure obtained in After Citadel	-	2 [illegible] (G1) $2\frac{1}{8}$ (G2)

Gas free compartments outside the citadel, i.e. Wireless Office, Laundry etc. were closed down by the users of the compartment.

(c) Experience showed that in order to obtain and maintain a reasonable pressure inside the citadel, particular attention must be paid to the tightening of door clips, gas-flap wing nuts and 'T' wedges. Finger tightness is not enough, and the use of hammers and levers is essential. Trouble was experienced with 'T' wedges, and these are considered to be most unsatisfactory. In order to get a satisfactory air tight joint they must be hammered home hard, and this makes the task of opening the flaps again very difficult. In addition much damage is done to the surrounding paintwork by constant and sometime inaccurate hammering. The large flaps on the inlets to the 25" fans are normally kept open, and considerable warping takes place during this time, making the task of closing these difficult. The maintenance effort involved in keeping these openings in good order is considerable.

(viii) Remarks and Recommendations.

The power supply and distribution system proved to be satisfactory.

2. Communications

(a) It is recommended that a pattern 12608 speaker and pattern 12599 microphone be wired permanently to the machinery broadcast system, and installed outside "A" Boiler Room hatch (See para (vi) (a).

(b) In order to improve communications to the upper deck it is recommended that extra speakers on the Ship's Broadcast System should be placed in the following positions:-

(cont)/..

SECTION V - ELECTRICAL

Para (viii) 2 (b) Cont/........

(a) "B" Gun Deck.
(b) Iron Deck- Port Side.
(c) "X" Gun Deck.
(d) Forecastle (To be made portable).

(See para. (vi) (b)).

(c) It is recommended that sound power telephones be wired to the T.C.B. in the A.B.C.D. H/Q at the Quarterdeck and Forecastle forward screen. There are two spare ways on this T.C.B. (See Para (vi) (c)).

3. Ventilation. The fact that positive pressure in both citadels was obtained and maintained was due to the attention paid to clips, wing nuts and 'T' wedges. Rough treatment was found necessary, and it is considered that this method is not only wasting time, but greatly adds to the maintenance bill. 'T' wedges proved to be most unsatisfactory and it is recommended that these be replaced by large non-ferrous wing nuts. +

4. It is thought that rather than use the larger supply fans for recirculation of air only, they could be used to supply fresh air at a much greater pressure than could be achieved with the Aerosol Filter Units. This could be implemented by modifying selected intake flaps to house appropriate filters. The pressure obtained within the citadel would undoubtedly be too great, and thus controllable non-return valves to the outer atmosphere would have to be fitted. By this method less attention to closing down need be paid, and far greater supply of clean fresh air would improve conditions within the citadel. Should it be necessary to stop this air supply owing to excessive fallout or base surge, then further flaps over the filters could be closed and the fans operated for recirculation only.

Note:-

+ This applies to non-machinery space fans only; a different recommendation is made in Section IV D(v).

Section VI - HABITABILITY

The number of officers and men involved in this operation was as follows:-

Forward Citadel	...	207
After Citadel	...	95
Machinery Spaces	...	4 on watch at any one time.

(ii) Air Supplies

(a) Fresh air from the outer atmosphere was supplied from the following Airfiltration Units:-

Forward Citadel - 2 in No. Wardroom Flat.
1 in No. Port Fan Compartment.
1 in No. Starboard Fan Compartment.

After Citadel - 2 in No. Abreast X Gunbay.

(b) Recirculated air was supplied to messdecks, flats, cabins, offices and auxiliary machinery compartments, etc., by means of nine fans in the forward citadel and four fans in the after citadel. All other fans were shut down.

(c) Air-conditioned compartments in the forward citadel, Type 293 Office, the T.S. and the Main Wireless Office were supplied with cool but unreplenished air for a part of the operation. Owing to the demand of pre-wetting and other services upon the firemain pressure it was not possible to keep the air-conditioning plant running all the time, and only when equipment was in danger of overheating was it switched on. (See section III(C)(i)5 of this report.)

(iii) Porton Filter Units (Type 2 Aerosol Filters)

The blower units produce a nominal flow of air of 200 cubic feet per minute each, but were believed to be over-run to deliver about twice this volume. This proved adequate with the numbers fitted to maintain positive pressures in both citadels throughout the operation.

2. Recirculation fans provided a reasonable flow for comfort throughout the ship with the exception of the following positions in which men were required to work:-

(a) Forward Switchboard Recirculation of this supply is taken from the crews' bathroom on No. 2 Deck, which proved exceptionally hot and humid. The single punkha louvre was quite inadequate to provide a reasonable circulation of air.

/(b) "A" Boiler ...

Section VI - HABITABILITY (Contd)

(b) "A" Boiler Room Cross Passage No. 2 Deck

A considerable amount of wild heat is discharged by a recirculating flap in the port passage, derived from workshops and machinery compartments below. This is aggravated by the use of the area by Engine room relief watchkeepers.

(c) Foreward Ship's Company Galley

It was noticeable on two occasions when the galley had been in recent use that highest ambient temperatures were reached in this region. It would prove impossible to make use of the main galley during such an operation.

(d) Forward Undressing Station

It was not possible to obtain a range of temperature readings in this compartment, since it was used as an air-lock throughout. Extreme heat exhaustion was experienced by the operators within three to four hours. Only one man proved fit enough to withstand the conditions for the full period of the operation.

(e) After Undressing Station

The remarks in (d) apply here also, except that the station was not used for Engine room reliefs and therefore did not come into full use until after cessation of fall-out.

(f) Operations Room

Despite the fact that Alteration and Addition Item 223, Parts (a) and (b) had recently been completed, the ventilation of this compartment falls short of operational requirements. Only four watchkeepers were employed in this operation as opposed to about 20 operators under wartime and action conditions. In addition only a small proportion of the electronic equipment was in use. Nevertheless the rate of air movement proved quite inadequate for comfort and, although extreme temperature and humidity conditions were not experienced the physical response was such as to suggest high CO_2 concentrations. (This could not be verified due to the lack of necessary equipment).

(g) Appendix "A" details the fixed and whirling psychrometer readings taken during two rehearsals and both operations at selected positions in both citadels.

/(iv) Subjective Assessment...

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Section VI - HABITABILITY (Contd)

(iv) Subjective Assessment of Physical Conditions

Conditions in the citadels during the operation may be divided into two main stages:-

(a) About 1½ hours relative discomfort associated with rapidly rising temperature and humidity until relative stability is reached, and the individual becomes acclimatised.

(b) A prolonged period of steadily increasing humidity which is not uncomfortable at first. After about 8 to 9 hours the first distress symptoms became apparent, depending upon the activity level of the subject. These symptoms are mainly associated with CO_2 excess aggravated by dehydration and physical discomfort due to sweat-soaked clothing. They are most marked where recirculated air flow is poor. The most noticeable symptoms were headaches, rapid shallow breathing, disproportionate fatigue, dry sore mouth and eyes.

2. Engine room watchkeepers although subjected to extreme conditions for a short period (30 to 40 minutes in ventilated suits or 2 hours in protective clothing and anti-gas respirators) generally withstood this well, and only one case of acute heat exhaustion was reported.

3. Unless air replenishment can be improved and some form of general temperature and humidity conditioning introduced, it is estimated that about fifteen hours is the maximum tolerable period for repeated closing down to ABCD State 1A.

(v) Morale Considerations

Only about one third of the ship's company were involved in this operation, and inactivity contributed greatly to the general discomfort. Movement was limited firstly to maintain shelter stations, and secondly to reduce heat production and oxygen consumption.

Although morale was very high throughout rehearsals and the operations, factors liable to contribute to lowering of morale might be assessed as follows:-

(i) Cramped quarters at shelter stations.
(ii) Humidity promoting excessive sweating.
(iii) Prohibition on smoking.
(iv) Limitation on the supply of hot and cold drinks.
(v) Temperature.
(vi) Monotony of type of food issued at action messing.

Section VI - Appendix "A"

Habitability Under Closed Down Conditions in Tropical Waters

Date: Commence (time)	1.5.56 1300	5.5.56 1500	16.5.56 1220	19.5.56 1230
Duration: Weather	4.15 Wind sl. 1/10 cloud Hot & dry	5.15 Wind sl. o/10 cloud Hot & dry	8.30 Wind f.1-3 2/10 cloud Hot & dry	9.00 W.f.3. 6/10 cloud Cooler, dry
Upper deck (psychrometer) and Sea Temp. at outset	88D 80W 82	82D 73W 84	82D 76W 79	78D 70W 77

Forward Citadel Wardroom								
Time Fixed psychrometer	1315	86D -W	1515	80D -W	1250	81D 72W	1400	86D 79W
Whirling "		88D 81W		82D 75W		82D 79W		86D 78W
Punkah louvres		87D 82W		- -		81D 74W		86D 79W
	1345	88D -W	1615	85D -W	1345	80D 74W	1500	83D 78W
		90D 85W		89D 80W		88D 78W		89D 81W
		92D 84W		88D 78W		88D 77W		87D 82W
	1440	89D -W	1720	87D -W	1450	84D 78W	1600	83D 81W
		93D 87W		90D 81W		88D 88W		91D 83W
		95D 84W		90D 80W		90D 90W		91D 83W
3 persons	1510	88D -W	1910	88D -W	1531	84D 77W	1705	85D 83W
		91D 87W		90D 82W		90D 88W		93D 84W
		95D 87W		92D 82W		91D 90W		93D 84W
	1540	88D -W	2030	85D -W	1620	85D 77W	1820	85D 83W
		91D 87W		88D 76W		94D 93W		93D 84W
		94D 87W		84D 72W		91D 90W		93D 84W
	1610	88D -W			1700	85D 77W	2025	87D 84W
		91D 87W				93D 92W		88D 85W
		94D 87W				91D 89W		88D 85W
	1645	88D -W			1815	86D 78W	2105	92D 83W
		91D 87W				90D 90W		88D 83W
		94D 87W				90D 88W		92D 83W
					1900	84D 78W		
						92D 85W		
						94D 82W		
					2015	85D 80W		
						90D 85W		
						94D 82W		
Cleansing Station	1320	93D -W	1525	86D -W	1255	93D 81W	1628	100D 86W
(Access frequently		91D 82W		86D 77W		91D 72W		95D 86W
made impossible by		92D 84W		P.L's off		Off		Off
use as air lock).	1442	95D -W			1702	101 89W	2110	107D 91W
		97D 86W				98D 95W		99D 89W
		97D 86W				Off		Off
..n Galley	1320	105 -W	1535	97D -W	1300	90D 78W	1405	89D 82W
		97D 88W		92D 80W		90D 75W		91D 83W
		99D 89W		94D 82W		88D 72W		89D 82W
	1350	103 -W	1625	96D -W	1536	90D 80W	1515	93D 85W
		98D 86W		90D 80W		92D 91W		88D 84W
		96D 86W		90D 80W		91D 91W		90D 83W
Nil	1444	102 -W	1720	97D -W	1705	92D 84W	1605	93D 84W
		97D 87W		91D 83W		94D 93W		92D 86W
		96D 87W		90D 81W		91D 90W		93D 84W

Section VI - Appendix "A" (Contd.)

Main Galley (Contd)	1512 102 -W	1915 98D -W	1808 93D 86W	1710 93D 87W
	97D 87W	94D 84W	94D 94W	94D 87W
	96D 86W	92D 81W	93D 92W	94D 86W
	1545 98D -W	2035 93D 0W	1905 94D 84W	1822 92D 86W
	97D 88W	88D 75W	95D 85W	93D 86W
	96D 88W	82D 72W	96D 85W	94D 86W
	1630 98D -W		2020 94D 84W	2016 91D 84W
	95D 88W		97D 85W	93D 84W
	94D 88W		97D 86W	94D 84W
				2122 90D 85W
				95D 85W
				95D 85W

Canteen Flat

Time Fixed psychrometer	1320 90D -W	1530 86D -W	1305 83D 72W	1406 83D 76W
Whirling "	88D 82W	85D 77W	82D 73W	85D 77W
Punkah louvres	Off	-	-	-
	1352 91D -W	1635 86D -W	1353 85D 75W	1520 85D 80W
	93D 84W	88D 79W	85D 76W	87D 77W
	93D 84W	-	-	-
	1445 92D -W	1735 88D -W	1455 85D 75W	1610 86D 83W
	93D 84W	99D 81W	88D 88W	85D 78W
	93D 84W	-	-	-
	1513 92D -W	1920 88D -W	1538 86D 77W	1715 85D 79W
	94D 86W	90D 83W	90D 89W	86D-80W
	94D 85W	-	-	-
12 - 16 persons	1547 92D -W	2035 87D -W	1628 85D 78W	1823 79D 84W
	94D 86W	86D 75W	90D 89W	87D 81W
	94D 86W		-	-
	1617 91D -W		1707 86D 77W	2015 87D 80W
	92D 86W		89D 89W	87D 80W
	93D 86W		-	-
	1643 91D -W		1810 87D 78W	2125 87D 80W
	92D 86W		91D 90W	90D 83W
	93D 86W		-	-
			1907 88D 80W	
			90D 88W	
			-	
			2022 85D 80W	
			90D 88W	
			-	

Forward Messdeck				
(Abaft paint locker)	1325 90D -W	1535 85D -W	1308 85D 73W	1412 84D 77W
	92D 85W	87D 76W	87D 76W	84D 77W
	91D 83W	88D 78W	88D 78W	84D 77W
	1353 90D -W	1635 86D -W	1355 86D 75W	1525 83D 78W
Nil	93D 85W	87D 78W	87D 78W	88D 78W
	93D 85W	88D 78W	87D 78W	85D 78W
	1447 91D -W	1740 87D -W	1500 87D 77W	1615 87D 85W
	93D 87W	88D 80W	88D 86W	84D 78W
	93D 86W	88D 80W	85D 83W	85D 80W
	1515 93D -W	1925 87D -W	1540 87D 78W	1720 84D 79W
	94D 86W	88D 82W	89D 88W	84D 79W
	93D 87W	88D 82W	87D 86W	84D 80W
	1550 93D -W	2040 84D -W	1632 85D 78W	1810 85D 80W
	93D 87W	85D 75W	89D 88W	85D 80W
	93D 87W	83D 72W	86D 85W	84D 78W
	1620 92D -W		1713 84D 78W	2006 86D 81W
	93D 87W		93D 87W	86D 81W
	93D 87W		97D 87W	86D 81W

Section VI - Appendix "A" (Contd.)

Forward Messdeck (Contd) (Abaft paint locker)	1656	92D -W			1807	82D 78W	2103	86D 83W
		92D 86W				88D 87W		88D 82W
		93D 87W				88D 86W		86D 81W
					1912	85D 79W		
						86D 80W		
						86D 79W		
					2028	86D 78W		
						87D 81W		
						86D 78W		
Steward's Messdeck	1330	82D -W	1540	82D -W	1312	80D 75W	1410	84D 75W
		88D 81W		83D 74W		82D 74W		84D 75W
		Off		Off		85D 74W		83D 77W
	1354	84D -W	1640	86D -W	1359	82D 75W	1530	85D 78W
		89D 78W		87D 80W		85D 79W		85D 78W
		90D 83W		87D 79W		85D 80W		83D 77W
28 persons	1448	90D -W	1745	87D -W	1510	87D 77W	1620	85D 80W
		90D 86W		88D 81W		89D 87W		85D 79W
		92D 83W		88D 80W		88D 86W		84D 80W
	1517	88D -W	1925	88D -W	1545	85D 77W	1722	86D 80W
		92D 87W		88D 82W		86D 86W		86D 81W
		93D 86W		88D 82W		87D 86W		86D 80W
	1552	89D -W	2045	85D -W	1635	86D 77W	1805	87D 81W
		93D 87W		84D 75W		88D 88W		86D 80W
		93D 87W		83D 72W		87D 87W		80D 78W
	1622	88D -W			1716	85D 77W	2005	86D 81W
		91D 85W				89D 87W		86D 81W
		92D 86W				87D 86W		87D 81W
	1700	88D -W			1805	88D 75W	2100	85D 82W
		90D 84W				88D 86W		85D 80W
		91D 85W				88D 86W		85D 80W
					1918	85D 79W		
						88D 81W		
25 - 30 persons						88D 81W		
					2032	86D 80W		
						88D 83W		
						89D 82W		
Watchkeepers' Messdeck	1330	86D -W	1545	84D -W	1315	83D 75W	1418	84D 77W
		87D 81W		84D 75W		85D 75W		84D 77W
		88D 82W		85D 75W		85D 75W		84D 77W
	1358	87D -W	1640	88D -W	1402	85D 75W	1535	85D 78W
		89D 83W		88D 81W		85D 76W		84D 78W
		91D 83W		88D 79W		87D 82W		84D 75W
	1450	90D -W	1745	88D -W	1505	88D 77W	1625	86D 80W
35 - 40 persons		91D 87W		88D 81W		89D 85W		85D 78W
		91D 87W		88D 80W		87D 85W		86D 80W
	1519	90D -W	1930	89D -W	1549	89D 77W	1725	86D 80W
		92D 86W		90D 84W		89D 86W		86D 80W
		92D 87W		89D 82W		88D 86W		86D 80W
	1558	90D -W	2045	87D -W	1640	89D 77W	1827	86D 80W
		93D 87W		86D 76W		88D 85W		86D 80W
		92D 87W		82D 71W		87D 85W		86D 80W

Section VI - Appendix "A" (Contd)

Watchkeepers' Messdeck (Contd)

Time	Reading	Time	Reading	Time	Reading
1625	91D -W	1720	89D 78W	2009	86D 81W
	92D 86W		89D 85W		87D 81W
	91D 86W		87D 85W		86D 81W
1701	91D -W	1810	88D 79W	2130	85D 82W
	92D 86W		88D 86W		87D 81W
	91D 86W		87D 85W		87D 81W
1716	91D -W	1924	89D 81W		
	93D 87W		90D 84W		
	92D 87W		89D 82W		

Petty Officers' Mess

20 - 30 persons

Time	Reading	Time	Reading	Time	Reading	Time	Reading
1335	88D -W	1545	84D -W	1320	84D 74W	1420	86D 78W
	88D 82W		86D 77W		85D 74W		86D 79W
	89D 81W		86D 76W		85D 75W		86D 79W
1400	89D -W	1645	87D -W	1406	85D 77W	1538	83D 80W
	90D 84W		88D 80W		87D 85W		84D 82W
	93D 85W		89D 79W		87D 85W		82D 81W
1452	91D -W	1745	88D -W	1510	87D 79W	1630	89D 83W
	92D 87W		89D 83W		89D 86W		88D 83W
	94D 83W		90D 82W		89D 86W		89D 83W
1524	91D -W	1950	89D -W	1552	86D 80W	1728	89D 84W
	92D 83W		90D 84W		90D 87W		90D 84W
	94D 87W		92D 82W		89D 86W		90D 83W
1600	91D -W	2045	87D -W	1645	86D 81W	1830	89D 83W
	92D 82W		87D 74W		90D 87W		91D 84W
	94D 87W		83D 72W		88D 86W		91D 83W
1628	91D -W			1723	86D 80W	2010	91D 84W
	92D 83W				90D 86W		89D 84W
	93D 87W				88D 86W		90D 84W
1705	91D -W			1837	88D 82W	2127	90D 84W
	91D 82W				92D 85W		91D 84W
	93D 87W				94D 92W		91D 84W
				1930	90D 82W		
					91D 84W		
					92D 85W		
				2036	90D 82W		
					91D 84W		
					91D 84W		

Transmitting Station

7 - 10 persons

Time	Reading	Time	Reading	Time	Reading	Time	Reading
1335	82D -W	1530	74D -W	1323	79D 74W	1425	91D 83W
	83D 78W		75D 67W		85D 72W		87D 83W
	77D 70W		68D 64W		82D 72W		91D 83W
1402	80D -W	1655	74D -W	1412	85D 78W	1545	91D 83W
	84D 79W		73D 65W		87D 86W		94D 85W
	75D 71W		68D 64W		87D 87W		96D 66W
1455	80D -W	1800	75D -W	1515	88D 86W	1635	93D 84W
	77D 72W		76D 68W		90D 88W		96D 86W
	75D 68W		70D 65W		90D 90W		95D 86W
1529	80D -W	1940	75D -W	1555	88D 82W	1730	92D 84W
	78D 74W		76D 68W		92D 91W		95D 86W
	74D 69W		70D 68W		91D 89W		96D 85W
1602	80D -W	2050	75D -W	1648	92D 88W	1815	92D 84W
	79D 74W		76D 68W		92D 89W		93D 88W
	74D 69W		69D 64W		91D 90W		93D 84W

Section VI - Appendix "A" (Contd.)

Transmitting Station (Contd.)	1630	80D -W			1726	91D 86W	2021	85D 75W
		78D 76W				92D 90W		87D 78W
		74D 69W				91D 89W		86D 77W
	1708	80D -W			1820	82D 76W	2115	84D 75W
		77D 75W				88D 86W		88D 78W
		74D 69W				83D 80W		82D 74W
					1920	81D 73W		
						85D 78W		
						84D 75W		
					2040	80D 72W		
						84D 79W		
						85D 76W		
Forward Switchboard	1337	104D -W	1555	98D -W	1330	96D -W	1422	96D -W
		97D 82W		95D 82W		93D 79W		94D 83W
		97D 82W		93D 80W		93D 79W		94D 83W
3 persons	1402	102D -W	1700	99D -W	1417	97D -W	1540	99D -W
		98D 88W		98D 84W		93D 89W		91D 85W
		99D 88W		95D 83W		94D 81W		95D 85W
	1458	103D	1800	100D	1505	98D	1633	101D
		99D 89W		97D 84W		95D 90W		97D 86W
		99D 89W		98D 85W		90D 87W		96D 86W
	1532	104D	1945	103D	1600	100D	1732	102D
		98D 89W		98D 85W		96D 91W		98D 87W
		98D 89W		98D 85W		98D 93W		98D 86W
	1604	103D	2055	102D	1650	100D	1818	103D
		99D 89W		98D 77W		95D 90W		96D 87W
		98D 83W		81D 74W		96D 90W		98D 86W
	1632	103D			1728	100D	2020	106D
		97D 90W				95D 90W		100D 87W
		97D 90W				95D 38W		100D 87W
	1710	103D			1820	101D	2100	105D
		97D 90W				94D 88W		100D 86W
		97D 90W				95D 86W		90D 87W
					1921	103D		
						95D 85W		
						94D 85W		
After Citadel Sick Bay	1325	95D	1500	84D	1315	90D 82W	1300	85D 80W
		97D 89W		83D 73W		90D 78W		85D 72W
		96D 87W		83D 72W		92D 77W		84D 70W
	1405	98D	1545	84D	1400	88D 82W	1430	85D 80W
		99D 90W		88D 80W		90W 78W		85D 77W
		99D 89W		89D 78W		92D 77W		85D 76W
0 - 3 persons	1510	98D	1630	89D	1500	88D 82W	1600	85D 78W
		99D 90W		86D 79W		90D 78W		85D 76W
		99D 89W		88D 79W		92D 78W		84D 74W
	1612	98D	1730	89D	1600	90D 82W	1730	85D 78W
		97D 91W		88D 81W		89D 77W		85D 76W
		98D 90W		88D 80W		90D 78W		84D 74W
	1710	99D	1830	89D	1700	90D 82W	1900	85D 80W
		99D 91W		88D 80W		89D 79W		85D 78W
		99D 91W		88D 80W		89D 79W		85D 74W

Section VI - Appendix "A" (Contd.)

Sick Bay (Contd.)	1740	95D	1930	88D	1800	87D 83W	2030	86D 82W
		95D 86W		88D 80W		89D 79W		87D 80W
		89D 82W		86D 80W		90D 80W		88D 79W
			2100	84D	1900	87D 83W	2200	88D 82W
				83D 73W		89D 79W		85D 80W
				82D 72W		90D 80W		84D 77W
					2000	87D 84W	2359	89D 85W
						89D 80W		89D 79W
						90D 80W		85D 75W
					2100	88D 82W		
						89D 80W		
						91D 81W		
					2130	88D 82W		
						89D 80W		
						91D 81W		
After Switchboard	1330	93D	1505	82D	1320	90D 80W	1305	85D 77W
		95D 87W		86D 74W		90D 77W		84D 76W
		95D 87W		84D 73W		92D 77W		84D 76W
	1410	98D	1550	89D	1405	94D 84W	1435	89D 80W
		97D 89W		89D 79W		90D 81W		88D 77W
		97D 89W		89D 78W		92D 78W		86D 77W
	1515	98D	1635	90D	1505	95D 84W	1605	91D 82W
		98D 92W		90D 80W		92D 81W		89D 77W
		98D 91W		89D 79W		92D 78W		86D 77W
	1617	99D	1735	93D	1605	96D 84W	1735	91D 82W
2 persons		98D 92W		91D 81W		90D 79W		89D 77W
		99D 91W		89D 79W		91D 78W		86D 77W
	1715	100D	1835	93D	1705	98D 85W	1905	91D 83W
		99D 92W		92D 82W		93D 80W		90D 78W
		99D 93W		89D 80W		93D 79W		88D 77W
	1745	98D	1935	94D	1805	98D 85W	2035	95D 88W
		98D 85W		93D 83W		95D 81W		92D 81W
		90D 82W		90D 81W		92D 80W		90D 80W
			2105	92D	1905	98D 85W	2200	94D 87W
				90D 75W		95D 81W		90D 80W
				85D 72W		92D 80W		94D 82W
					2005	98D 89W	0005	96D 85W
						95D 83W		93D 81W
						92D 80W		86D 76W
					2105	98D 88W		
						97D 83W		
						92D 82W		
					2135	100D 88W		
						98D 85W		
						99D 84W		
After M.E's Messdeck	1335	92D	1510	86D	1325	86D 80W	1310	84D 77W
		93D 86W		86D 74W		87D 78W		84D 77W
		95D 87W		84D 73W		90D 78W		84D 76W
	1415	94D	1555	87D	1410	87D 82W	1440	85D 78W
		95D 89W		87D 79W		89D 79W		85D 77W
		97D 89W		87D 78W		90D 79W		85D 77W
36 persons	1520	95D	1640	88D	1510	87D 82W	1610	85D 77W
		95D 89W		87D 79W		89D 79W		83D 77W
		97D 89W		88D 78W		90D 79W		85D 77W

Section VI - Appendix "A" (Contd.)

After M.E's Messdeck (Contd.)

1622 96D	1740 89D	1610 88D 82W	1740 85D 77W
95D 90W	88D 81W	89D 79W	83D 77W
97D 90W	88D 80W	90D 79W	85D 77W
1720 96D	1840 90D	1710 90D 85W	1910 86D 78W
96D 92W	90D 82W	90D 80W	85D 77W
98D 92W	89D 80W	90D 80W	86D 78W
1750 94D	1940 90D	1810 88D 84W	2040 87D 82W
92D 84W	89D 82W	89D 81W	88D 81W
89D 83W	89D 83W	90D 80W	88D 81W
	2110 86D	1910 88D 84W	2210 86D 80W
	85D 75W	89D 81W	87D 81W
	84D 72W	90D 80W	86D 80W
		2010 90D 85W	0009 88D 80W
		89D 82W	87D 79W
		92D 81W	86D 76W
		2110 90D 85W	
		90D 83W	
		92D 82W	
		2140 90D 85W	
		90D 83W	
		92D 82W	

After Passage

No punkah louvres

3 persons

1340 95D	1515 87D	1330 89D 78W	1315 83D 76W
94D 86W	87D 76W	88D 78W	83D 76W
1420 98D	1600 89D	1415 90D 80W	1445 85D 78W
96D 89W	90D 82W	89D 79W	84D 77W
1525 98D	1645 90D	1515 90D 80W	1615 82D 78W
95D 90W	90D 80W	89D 80W	83D 77W
1627 95D	1745 90D	1615 90D 80W	1745 82D 78W
95D 90W	90D 84W	89D 79W	83D 77W
1725 96D	1845 89D	1715 90D 84W	1915 86D 80W
95D 90W	89D 81W	89D 80W	84D 77W
1750 93D	1945 86D	1815 90D 85W	2045 86D 81W
92D 83W	85D 73W	90D 82W	86D 81W
	2115 86D	1915 90D 83W	2215 85D 81W
	85D 73W	92D 83W	86D 80W
		2015 90D 83W	0014 87D 81W
		92D 83W	87D 79W
		2115 90D 83W	
		92D 83W	
		2145 90D 80W	
		92D 83W	

Chief Petty Officers' Messdeck

32 persons

1345 89D	1520 84D	1335 87D 76W	1320 85D 75W
90D 85W	85D 75W	85D 76W	82D 75W
92D 85W	83D 74W	87D 76W	83D 74W
1425 91D	1605 86D	1420 88D 78W	1450 84D 77W
92D 87W	87D 80W	87D 77W	83D 76W
93D 87W	89D 79W	88D 76W	84D 77W
1530 93D	1650 88D	1520 88D 78W	1620 85D 77W
94D 87W	88D 79W	87D 77W	85D 76W
94D 89W	89D 79W	88D 76W	85D 76W
1632 95D	1750 89D	1620 88D 79W	1750 85D 77W
94D 90W	88D 82W	88D 78W	85D 76W
95D 89W	88D 79W	89D 77W	85D 76W
1730 94D	1850 89D	1720 88D 80W	1920 88D 77W
95D 90W	88D 80W	89D 79W	84D 76W
96D 90W	89D 79W	89D 78W	85D 76W

Section VI - Appendix "A" (Contd.)

Chief Petty Officers' Mess (Contd)	1755 92D 89D 82W 85D 80W	1950 88D 88D 80W 89D 79W 2120 86D 86D 75W 83D 73W	1820 89D 81W 89D 80W 89D 78W 1920 89D 81W 89D 80W 89D 78W 2020 89D 82W 89D 82W 89D 82W 2120 89D 82W 89D 82W 89D 82W 2150 89D 82W 89D 82W 89D 82W	2050 87D 80W 86D 79W 86D 79W 2220 88D 81W 87D 79W 86D 78W 0009 85D 75W 84D 76W 81D 72W
After Seamans' Messdeck 32 persons	1350 92D 95D 86W 94D 86W 1430 94D 95D 88W 96D 89W 1530 94D 95D 89W 96D 89W 1637 94D 95D 90W 95D 90W	1530 84D 84D 73W 82D 72W 1610 86D 87D 79W 88D 79W 1700 88D 88D 80W 90D 80W	1340 87D 77W 87D 76W 88D 76W 1425 87D 77W 88D 80W 88D 77W 1525 89D 79W 88D 79W 88D 77W	1325 84D 76W 84D 76W 83D 75W 1455 85D 77W 84D 77W 85D 76W 1625 85D 78W 85D 76W 84D 74W
	1735 94D 95D 91W 96D 91W 1800 90D 90D 83W 85D 80W	1800 88D 89D 82W 89D 81W 1900 88D 89D 82W 90D 81W 2000 87D 86D 81W 88D 80W 2130 88D 84D 74W 82D 71W	1625 89D 79W 88D 79W 89D 79W 1725 89D 80W 88D 80W 89D 79W 1825 89D 80W 88D 80W 89D 80W 1925 89D 80W 88D 80W 89D 80W 2025 89D 82W 89D 82W 90D 81W 2125 89D 82W 89D 82W 90D 81W 2155 89D 82W 89D 82W 90D 81W	1755 85D 78W 85D 76W 84D 74W 1925 86D 80W 84D 76W 86D 74W 2055 87D 80W 86D 80W 87D 79W 2225 86D 82W 85D 80W 84D 77W 0024 84D 75W 83D 75W 80D 73W
Operations Room 3 persons		Maximum fixed psychrometer 97D 90W	Maximum fixed psychrometer 89D 83W	1815 90D 89D 83W 91D 83W 2020 92D 90D 82W 90D 82W 2100 93D 91D 82W 90D 82W

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Section VII - Radiac Instruments

A list of radiac instruments supplied to the ship for the operation is contained in Appendix A. This appendix also shows a list of those instruments which should be carried by this class of ship on any future trial of this nature.

(ii) Contamination meter No. 1

These stood up well to constant use and a certain amount of rough treatment. They required very little maintenance. A possible improvement would be a wire guard round the tube CV 2246 to protect it from damage. One of these tubes was replaced due to an accidental knock. However, these instruments had their limitations from the monitoring point of view

2. In the first place, because of the low dose rates received, monitoring throughout the ship had to be done with contamination meters No. 1, those supplied to DIANA being supplemented by three battery-operated sets borrowed from the scientific staff. These are not, of course, designed for this sort of work, and their heaviness made monitoring a somewhat slow and tiring business. However, once radioactivity built up above 10mR, accurate monitoring was hampered by the fact that no instrument was held which would carry on giving good low-scale readings, from the point the contamination meter ceased to register, the survey meter (No. 2) supplied being insufficiently sensitive to give accurate readings below about 300 mR. This gap could have been filled by the supply of four survey meters number 3 in place of the survey meters number 2 which in the event were only used for training.

(iii) Quartz Fibre Dosimeters

No readings were recorded on these dosimeters during the operation, but there was an electro-static leakage rate of from 0.2 to 0.3 r per week on dosimeters QF-2A. In the main only this type were issued. The original number supplied to the ship (54) was found to be quite inadequate, and a further 75 were flown out, so they had a wide use. Despite this, only one became defective, and two were found to be unserviceable on receipt, which demonstrates the fact that they are robust and reasonably sailor-proof. Comments as a result of experience with these instruments are:-

(a) The rubber cap is easily detached and lost, and the older type with the screwed cap is considered preferable.

(b) The serial numbers should be embossed on the body since the present method of "transfer" printing wears off very quickly. In DIANA, selotape was fitted over the numbers as a temporary expedient.

(c) It is suggested that the clip be pierced so the dosimeters can be worn on a lanyard round the neck if necessary. When the Engineroom crews were wearing special protective suits there was no part of the suits where the dosimeter could be properly clipped.

/(iv) Charging Units . . .

Section VII - Radiac Instruments (Contd)

(iv) Charging Units JSC 6665/110004

Out of the three supplied two became defective after charging approximately 200 dosimeters, due to the cam operated by the milled finger wheel breaking. The construction of the cam is weak, being of plastic material, and as it is drilled in the middle to accommodate the actuating pin which bears on the wheel, breakage at this point is almost inevitable with much use.

(v) Film Badges

150 Film Badges were issued to selected personnel throughout the ship. No significant dose was recorded in either event, but this was only to be expected as the average fog level (minimum reading) of these films is 50 mR.

(vi) Issue of Quartz Fibre Dosimeters and Film Badges

These were all issued from the Sick Bay where record sheets were maintained for each officer and man showing his particulars, particulars of the instruments issued to him, and his Action and Shelter Station; and when the instruments were returned, any doses recorded. It was found necessary to centralise in this way to obviate losses and to ensure that readings were properly recorded.

(vii) Flash Dosimeters

On the advice of the Senior Scientific Officer, R.N.S.S., these were not issued during the operation since the anticipated radiation doses would be too small. However, the 18 artificially dosed dosimeters supplied are being worn, and a further report will be forwarded on their durability and whether any fall in radiation dose occurs.

(viii) Flash Dosimeter Reader Instrument

Although this instrument was not used operationally, the lamp has been run for a total of four hours without defects. The meter appears to be sluggish and at times gives a different reading for the same dosage.

(ix) Recommendation

The lack of a counting device for air samples and smear tests was very keenly felt. Fortunately the ship was able to make use of the instrument held by the Scientific Staff, but this would not, of course, normally be available. It is recommended that a counting instrument suitable for service use should be developed without delay.

(x) Effect of Radar Transmissions on Radiac Instruments

A Contamination Meter No. 1 (J.S.C. No. 666/110107) was subjected to the transmissions from Radar Type 275. No effect was observed until the probe unit was held actually in the beam from the transmitter nacelle at a distance of 3 feet from the perspex window. At this point intermittent breakdown of the Geiger counter was experienced as indicated by the meter needle going hard over full scale. The effect was increasingly pronounced as the meter was brought nearer the nacelle, until, when touching the perspex window, the meter needle was hard over continuously.

/Meter readings . . .

Section VII - Radiac Instruments (Contd.)

Meter readings due to a radioactive source outside these limits mentioned above were unaffected by Radar Transmissions. Similar effects were observed in the Radar Type 293 Office within the Citadel where stray radiations from the transmitter were sufficient to cause a breakdown of the Geiger Tube at distances of 12" or less from the waveguide.

(xi) Conclusion

It is considered that accurate readings of radioactive radiations can be obtained in any part of the ship providing the instrument used is not held nearer than 3 feet from a Radar Transmission.

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC

Appendix "A" to Section VII

List of Radiac Instruments carried in DIANA for Operation MOSAIC and list of those it is recommended should be carried on any future trial in this class of ship.

Reference No.	Description	No. Carried	No. recommended to be carried
6665-110001	Dosimeters Q.F. No. 1	2	60 /
-110101	" " No. 2A	54 + 75	150
-110003	" " No. 3	10	10
11091	" " No 4	10	nil
11061	" " No 5	3	nil
-110004	Charging Units	2	2
-110107	Contamination Meters No. 1 Mk II (Mains Operated)	2	2
-110107	Contamination Meters No. 1 Mk II (Battery operated)	1	4 x
-110031	Telephone Headsets	3	6 x
-110028	Mains Units	2	2
-110030	Battery Units	1	4 x
-110027	Radiac slide rules	3	1
-110130	Survey meters No. 2	4	4 x
-110123	Survey meters No. 3	NIL	6 x
	Dose Rate Trainer No. 1	2	2
-110098	Jig Calibration (with radioactive source Type G) for survey meter	1	1
-110099	Jig Calibration (with radioactive source Type H) for contamination meter	1	1
	Sources Type B	10	10
1069	Buttons, luminous	20	20
	Film Badges	150	1 for each man ≠ in the ship plus 5% spare (for each explosion).
	Flash dosimeters (phosphate glass)	212	200 ≠
	Reader for Flash dosimeters (phosphate glass)	1	1 ≠
	Set of spares for Flash dosimeter reader	1 set	1 set ≠

/ Includes 30 for Engineroom crews. x Includes 2 for engineroom monitoring.
≠ Only if it is anticipated that any member of the Ship's Company is liable to receive a total dose of at least 3R.

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H.M.S. DIANA,
at ADEN.

17th August, 1956.

No. 01/29
SECRETARY OF THE ADMIRALTY
SUPERINTENDENT,
ADMIRALTY RESEARCH LABORATORY,
TEDDINGTON
COMMANDING OFFICER, H.M.S. PHOENIX
COMMANDING OFFICER, H.M.S. NARVIK

OPERATION MOSAIC - FLASH DOSIMETERS

The following report is forwarded in accordance with D.T.S.[illegible] letter No. T.S.D.4033/56 dated 1st February, 1956, and in continuation of H.M.S. DIANA's Report on Operation Mosaic, Section VII, paragraph (vii).

2. Twelve Pattern 6665-110128 and six Pattern 6665-[illegible]128 (White Spot) phosphate glass flash dosimeters were issued to selected personnel working in different parts of ship for a period of two weeks.

3. The records taken of dose fading of dosimeters during this period are shown in the Appendix. No records could be taken of the "White Spot" type since no jig is available to open these.

4. The dosimeters appear to be robust and capable of withstanding normal usage.

J.R.S. Owen

CAPTAIN

Enclosure - Appendix

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(Appendix to the Commanding Officer, H.M.S. DIANA's No. 01/29 of 17th August, 1956)

- -

PHOSPHATE GLASS DOSIMETERS

Dosimeter No.	Dose Before Issue	Dose On Return	Fade during period of two weeks trial in Roentgens
000535	520r	450r	70
000511	520r	420r	100
000537	520r	420r	100
000547	590r	600r	---
000545	470r	310r	160
00054[illegible]	520r	500r	20
000551	520r	470r	50
000542	480r	440r	40
000502	450r	420r	30
000532	515r	450r	65
000544	468r	400r	68
000529	559r	520r	39

SECTION VIII - THE ARMAMENT

A - General

The experiences related in this section are the combined result of HOTSHOT and FLASHLIGHT, for in the first insufficient airborne contamination was found (practically all was due to the pre-wetting pumping contaminated water over the ship) but the effects of pre-wetting could be observed. In the second, sufficient airborne contamination was available for some conclusions to be reached.

2. In early discussions with the Admiralty no requirements for particular armament trials were enunciated but it was agreed that a proportion (then 50%) of the armament should remain uncovered. Later, upon the advice of the R.A.N. A.B.C.D. Officer, who was experienced in decontamination, this proportion was modified. A table showing the state of upper deck positions is appended to this section (Appendix A).

SEC...

SECTION VIII - THE ARMAMENT

B - Gunnery

30 dosimeters Q.F. 2.A. (0-5R) were distributed on and within the gun armament, in order to discover the pattern of contamination. However at no time was sufficient contamination received to register upon such coarse instruments. The results of readings taken with contamination meters No.1 after the event FLASHLIGHT form the tables in Appendix B to this section.

2. As stated in Section III, A5 the ship's staff set to work to investigate the possibility of devising covers for the C.R.B.F.D. and S.T.A.A.G. which would;

(a) Protect the Crews.
(b) Protect the machinery.
(c) Permit normal operational use.
(d) Permit normal maintainance.

3. Before going on to describe the covers and the results it will now be convenient to describe the results of leaving M.1. S.T.A.A.G. uncovered.

(ii) The Uncovered S.T.A.A.G.

M.1 S.T.A.A.G. had faced up to three rehearsals each using the pre-wetting, with the result that on each occasion all communication gear was put out of action and it was necessary to strip the breech and auto loader assembly for cleaning, and to give a thorough sponge out.

2. Some three days before HOTSHOT the Range Box had been opened in the course of routine maintainance and cannot have been closed completely tight afterwards. During HOTSHOT the pre-wetting was operating for 8 hours - a most realistic time (F.O.T.I. 1601 dated 4 - 2 - 56 by inference) at the end of which inspection of the mounting revealed the following:-

(a) Breech, Bore and Auto Loader Assembly reduced to a very bad condition as expected. Time to remedy - 12 hours.

(b) Water had entered the Range Box for reasons given in Section B, Para 1 above reducing all parts to a very rusty condition. Time to remedy - 3 days.

(c) All communications gear was put out of action, time to replace - ½ day.

(d) Water had entered the X display through the gasket which was found to have a split in it. The water then entered the boxes by way of the air vent system. The extensive damage caused by this together with some other defects found is listed in Appendix C to this section. Time to remedy - not yet remedied (28th June, 1956).

In short the mounting was reduced to uselessness for 3 days and to visual fire with fly through range deflection only for, as yet, an unspecified period.

/3. Before FLASHLIGHT...

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SECTION VIII - THE ARMAMENT

3. Before FLASHLIGHT the gaskets were replaced and resealed as necessary, each being coated lightly with lanolin. No further damage was caused by the ingress of water to closed boxes. The pre-wetting was on for 9 hours.

4. The first table in Appendix B shows the random samples taken of the radiation component present amongst the contamination on M.1 S.T.A.A.G. after FLASHLIGHT. it is inferred from this that two general effects had occured;

(a) Pre-Wetting tends to wash the loose contamination down into awkward places and places difficult of access.

(b) The construction of the mounting prevents pre-wetting from getting at many "pockets".

These effects together with the greasing and oiliness inevitably associated with this type of mounting means that loose contamination tends to stick to the mounting and accumulate in positions which are extremely difficult to decontaminate.

5. At the point 8 [illegible]/hour (see table 1 of Appendix B) the radiation component can of course be taken as safe. However a smear taken of the relevent 4 or 5 square inches at H + 24 showed a count (on a counter of [illegible]iciency 15%) of 1,770 per second this being more than one half Micro Curie * 10,000 the peace-time tolerance for loose contamination.*

6. The ship's proved best decontamination team was set to work to clean this. Shale oil was employed but it was only after 3 attempts and $1\frac{1}{2}$ days work that the count fell to about 5 counts per second. At this point it was left to weather.

7. A similar point (850 counts/sec T.A.S. Section VIII,E (v) was reduced to 0.97 counts per second in one attempt. The difference lay entirely in the fact that the second point was easily accessible and the place in the S.T.A.A.G. was not.

.... on the authority of the ship's Senior Scientific Officer, Mr. D.M.C. Thomas, B.A.

(iii) The Special Covers

It will be clear from the above that the fifth and most important requirement must be added to those in para B.2.

(e) To exclude loose air-borne contamination and hence eliminate the necessity for ~~internal~~ external decontamination.

2. The ship's staff with these considerations in mind set to work, assisted by Fremantle Yard and Singapore Dockyard in the construction, to design and build covers to meet the requirements for the C.R.B.F.D. and M.2 S.T.A.A.G. Of these the C.R.B.F.D. appeared to offer the best chance of quick achievement and so was attacked first. The preliminary version was ready for HOTSHOT. The final version for the C.R.B.F.D. and a cover for M.2 S.T.A.A.G. were both ready for FLASHLIGHT.

/3.A selection...

SECTION VIII - THE ARMAMENT

3. A selection of photographs and drawings of these covers forms Appendix D to this section of the report.

4. Both covers were necessarily hurriedly built and of materials which were to hand. As a result the C.R.B.F.D. cover particularly, being of steel, is 550lb in excess of the original arrangement and the S.T.A.A.G., where much canvas was used in place of steel, some 180lb in excess. For this reason both will be removed. However this will not invalidate the findings and a suggested solution will be offered.

(iv) C.R.B.F.D. Cover.

The general form may be seen from Appendix D.

2. Two canvas panels in front permit access for maintainance and the centre panel of canvas forward takes the place of a moulded plastic cover over the radar dish, the production of which was beyond standard dockyard capability.

3. Aimer and Controller both have perspex windows. These stand in for proper armoured glass arrangements. The intention being that the Aimers window should slide back clear on rails (c.f. aircraft cockpit canopy) and the Controller would ideally be in a hood like that on the M.R.S.3 Director.

4. The inside is cork-covered for noise damping but this is not adequate and some more effective acoustic lagging must be used.

(v) S.T.A.A.G. Cover

Again the general form may be seen from Appendix D.

2. Once again the mounting is enclosed but the aimers and controllers hoods are more crude and canvas panels, round the back to the sureba plate each side, substitute for proper panels, doors and access flaps over the hoists. The radar dish is again canvas covered in default of a moulded plastic cover.

3. It is necessary to use canvas blast bags but despite the apparent difficulties, Singapore Yard made a pair to compete with elevation, lateral deflection and recoil.

(vi) Results.

Inspection of table in Appendix B will show that the radiation component was down on that on M.1. This was the shielded radiation component from the outer surface of the cover. No loose contamination entered either cover.

2. Both mountings can be operated with covers fitted although in the S.T.A.A.G. the controllers joystick will have to be moved up and the noise level in the C.R.B.F.D. is too high. It is considered that this noise problem is capable of solution by proper lagging. It is known that the perspex would not stand up to blast (but see (iv) 3 above).

/3. Maintainance is not.....

SECTION VIII - THE ARMAMENT

3. Maintainance is not hampered except that in the C.R.D.F.D. a small O.A. must be selected to work on the fore side of the tachometric box.

4. No pre-wetting water entered the covers.

5. Materials

(a) Canvas should be avoided where ever possible as it tends to have contamination soak into it after period of more than 1 hour. The stowage of canvas is also a problem. For this operation the ship had two tons of special canvas gear which, together with the usual awning gear etc., filled the tiller flat and covered all "X" Gundeck. Some sort of plastic which can be stowed in a compressed state is indicated.

(b) Perspex appears to be more "sticky" than painted metal or glass to contamination. This in the ratio of about 15, 10, 8 respectively. (Appendix B).

(vi) Conclusions.

The principle of the necessity of covering open weapon directors and mountings is established.

2. It is demonstrated that this can be done with little modification and without prejudice to use or maintainance of the equipment. Whether the fire power of, say, a S.T.A.A.G. warrants this is debatable but it is considered vital for the C.R.D.F.D. and for equipment to come (M.R.S.3. L 70 Bofor mounts etc.).

3. Covers should be as smooth and rounded as possible. They should be all-embracing. Access panels, doors and flaps should be flush fitting as is a squash court door when closed.

4. Perhaps here is a field where the light weight and resilient properties of plastic might be put to advantage.

(vii) Other Positions

The 4.5" Turret weathering was found to deflate slowly when left unattended for long periods. This was countered by putting a small canvas cover over the reverse slope of the mantlet plate. It is considered that this was due to the weathering being four months since last receiving dockyard attention. ~~(Photograph see Appendix D)~~.

2. These turrets were decontaminated with ease immediately after the event in the washing. No detectable contamination existed at H + 24.

SECTION VIII - THE ARMAMENT

C - Effect of A.B.C.D. State 1A on Fighting Efficiency

When closed down at A.B.C.D. State 1A it is of course desirable to have all doors closed. This has the folowing effects upon the Gun Armament;

(a) The C.R.B.F.D. Power Room is isolated from the C.R.B.F.D. so that the after citadel must be broken to get at the switches there or to adjust the F.C.U.

(b) The forward citadel must be broken to supply befors ammunition from the magazinsto the mountings.

(c) Both citadels must be broken to clear empty cartridge cases from the 4.5" gunbays.

2. The above effects are common experience but the factor which gave most trouble was that the communication systems (Broadcast and Telephone) and gun direction switching system were built with the Bridge as Primary Command Position. It was found necessary to duplicate the Alarm Rattler Push, Armament/Ship's Broadcast Linking Switch and Ship's Broadcast Microphone in the Operations Room in order to have sufficient flexibility of control.

3. It is recommended that the primary position from all points of view must be within the citadel.

H.M.S. DIANA'S REPORT ON OPERATION MOSAIC

SECTION VIII - THE ARMAMENT

D - Use of Radar to track the Radio Active Cloud - Estimation of Fall Out Direction

In event HOTSHOT no sign of the Radio Active cloud was seen on Radar type 293; the only cloud in a clear sky. During FLASHLIGHT ground zero was well beyond maximum radar display range.

2. In the period before FLASHLIGHT a series of meterological balloons were released and tracked by radar type 275 in order to determine the equivalent constant winds from various heights. This process is completely analagous to the determination of Ballistic E.C.W's except that all height weighting factors are unity.

3. In the general case the fall out may be assumed to be distributed about the E.C.W. to the height of the centre of the cloud.

4. The track and rose of fall out F.C.W's of the balloon released 25 minutes before G2 was exploded is attached as Appendix C to Section 1.

5. Experience recommends that, in order to acheive the necessary 40,000 feet plus, save time and avoid operator boredom, balloons ascending at 1,500 or better 2,000 feet per minute, would be advantageous.

SECTION VIII - THE ARMAMENT

E - Torpedo and Anti-Submarine

When the ship is closed down in A.B.C.D. State 1A it is still possible to operate the Asdic sets. The Asdic Instrument Room is inside the citadel but the D.G. Compartment is not. The Squid Projectile Room is a gas free compartment but will not be manned as it has no access to the after citadel.

2. The problem confronting this department was to keep the weapons free from contamination if possible and if not, to investigate the difficulties of decontamination.

(ii) Preparation

The T.A.S. Armament was in the same state for both events, that is, with the forward tubes and the squid covered with canvas as were the Torpedo Pedestal Sight, the Sided Sights, the Unifoxer and the Bathy-thermograph reels. The After tubes were left uncovered in the action state and trained aft. Three 21" Mk.1X^{xx} torpedoes were carried in these tubes.

2. Some of the working parts of the tubes were left with grease coverings but other parts were cleaned before the event.

3. Pre-Wetting covered most of the mounting but the breeches and rear doors were not affected as they are covered overhead by an extension of the after funnel deck.

4. A quartz fibre dosimeter 2A was placed inside the blast screen although it is appreciated that this will not be manned and a second dosimeter placed inside "X" tube in the rear of the torpedo.

(iii) Hotshot

No contamination of any kind was found after this event and there was no reading on either dosimeter.

(iv) Flashlight

Although neither dosimeter gave a reading, considerable activity was found in the grease around the breeches and rear doors ~~touched~~ by pre-wetting. High readings were also obtained from grease patches on other parts of the mounting which had not been removed due to their inaccessibility. All equipment covered by canvas was free of contamination. <-S untouched

(v) Decontamination

The after tubes were decontaminated by two ratings wearing protective clothing and Anti-Gas Respirators. Shale Oil and rags were used for this task and proved extremely effective as shown by the results of the smear tests listed below:-

Smear Test taken before decontamination gave 85,000 counts/100 secs.

Smear Test taken after decontamination gave 97 counts/100 secs.

/(vi) Recommendations......

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SECTION VIII - THE ARMAMENT

(vi) Recommendations

That some type of plastic covers be provided for tubes and mortars. If there is time to put on such a cover it would obviously be the best prevention against radioactive fallout.

2. If it is envisaged that future development torpedoes are to be launched from this type of mounting 21" (Pentad Revolving Mk4) it is strongly recommended that the whole design be "cleaned up" to facilitate easier decontamination, maintenance and general day to day cleaning. This could be improved by putting all external tube fittings under cover.

3. The grease used on tube fittings for this operation (L.G. 280) retains radioactive fall out that may come in contact with it and is also washed away by pre-wetting. As it is essential that working parts be greased there is a requirement for a grease that forms an outer skin to which fallout will not adhere and which can withstand continual drenching with salt water.

SECTION VIII - THE ARMAMENT

APPENDIX B

Table I

M.R/hour at H + 24

Position of Count.	M.1.	M.2.	C.R.B.F.D.
Flash Eliminator.	1.5	2	-
Barrels (Under.	2-3	2	-
Barrels (Over.	1.5	1.5	-
Barrel Springs (Under.	3-3.5	1.5	-
Barrel Springs (Over.	2	3	-
Zareba Plate front (mean)	0.8	1	-
" " back (mean)	0.6	0.25	-
Special Covers over	-	1	1.5
" " sides (mean)	-	-	1
" " covers (mean)	-	1.5	-
" " perspex (mean)	-	2	1.75
" " blast bags under	-	1.75	-
" " blast bags over	-	3	-
Auto Loader (over	3	1.7	-
Auto Loader (under	1.8	1.2	-
Auto Loader (left	1	1	-
Auto Loader (right	1	1	-
Tacho Box (Deck under	4	1	0.5
Tacho Box (Under	0.8	1	0.6
Tacho Box (Over	0.1	1	0.8
Tacho Box (Rear	[illegible]	[illegible]	[illegible]
Tacho Box (Front	[illegible]	1	0.5
Tacho Box (Left	1.8	1	0.6
Tacho Box (Right	4	1	0.6
Radar Dish (Front	1	1	1
Radar Dish (Back	1.8	0.8	1
Aimers (Sight	1	1	0.5
Aimers (Seat	4	0.7	0.5
Aimers (Joystick	1	1	0.6
Right ~~Training~~ Trunnion Under	8	1.25	0.6
Left Hoist (Top	0.8	0.6	-
Left Hoist (Bottom	1	1	-
Right Hoist (Top	1.5	0.5	-
Right Hoist (Bottom	3.5	0.8	-

/Radar 262.......

Copy No. 15

SECTION VIII - THE ARMAMENT

APPENDIX B (Continued)

Table I

MR/hour at H + 24

Position of Count.		M.1.	M.2.	C.R.B.F.D.
Radar 262	Over	2	0.8	-
	Front	1	1	0.8
	Outside	0.5	0	1
	Inside	0.4	0	1
	Back	0.4	0.5	1
Controller	Top	1.2	1	1
	Bottom	1	0.5	0.5
	Left	1.2	0	0
	Right	1.3	0	0
Amongst the piping	Right Front / Left Front / Right Rear / Left Rear	2-4 spots of 6-7	1-1.5	-
Oil Sample		1.5	1.0	-

SECTION VIII - THE ARMAMENT

APPENDIX B

Table IV

M.R/hour at H + 26

Position of Count.	Mk.6 Director.	Mk.5 Twin B.fcr.
Over.	1.2	NONE DETECTABLE WHEN UNCOVERED
Front Windows.	0.8	
* Radar Nacelle Front	4	
Support - mean	0.2	
Inside (Roof	0.8	
Inside (Aimer	0.8	
Inside (Rate Keeper	0.8	
Inside (Layer	1	
Inside (Trainer	1	

* Pre-Wetting hardly covered these.

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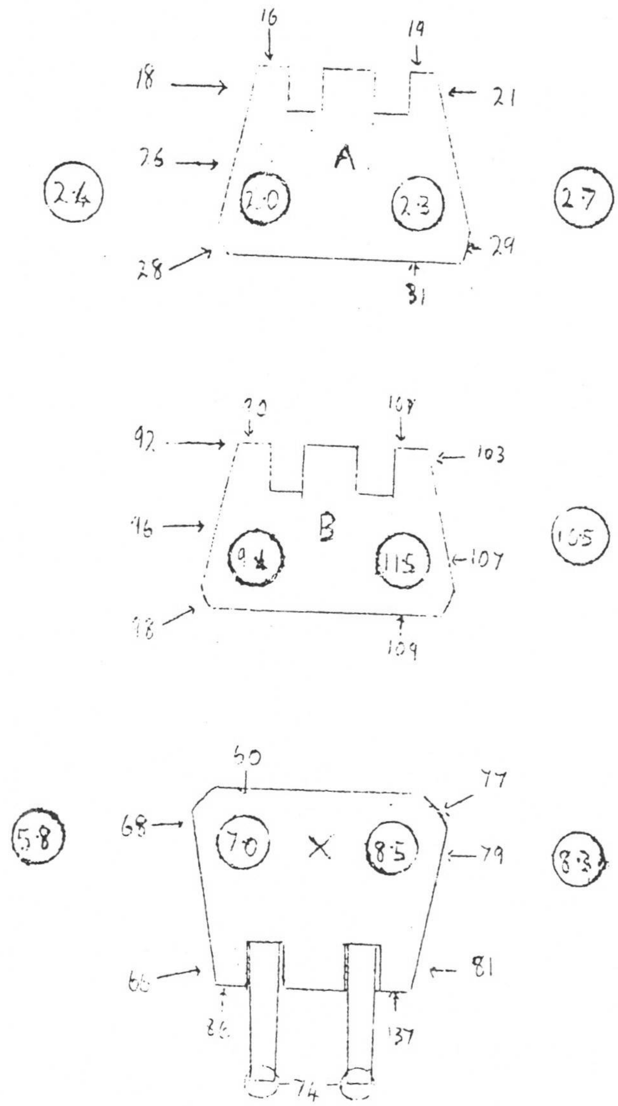
SECTION VIII - THE ARMAMENT

APPENDIX D

Table III



Arrows point to pre-numbered marked spots. Circles indicate similar places on deck and turret roof.

SECTION VIII - THE ARMAMENT

APPENDIX B (Continued)

Table III

HOTSHOT at H + 10
FLASHLIGHT at H + 12

"A" Turret POS'N.	HOTSHOT.	FLASHLIGHT.	"B" Turret POS'N.	HOTSHOT.	FLASHLIGHT.	"X" Turret POS'N.	HOTSHOT.	FLASHLIGHT.
16.	480	600	90	–	–	86	–	–
18.	980	600	92	–	–	66	–	–
26.	1000+	1000	96	–	–	68	–	–
28.	1000+	–	101	–	–	60	–	–
21.	1000+	700	103	4	5	137	–	–
29.	1000+	1000+	107	5	5	81	–	–
31.	–	–	109	–	–	79	4	–
24.	1000+	400				77	–	–
27.	1000+	1000				83	10	10+
						58	10	4
20.	600	1000+	94	3	2	70	10	–
23.	1000+	500	115	2	2	85	–	–
						74	10	2

Note:-(i) "A" is in counts per second at 6 feet.
"B" and "X" in M.R./hour at about 1 foot.

(ii) 100 counts per second at 6 feet = 4 M.R/hour at 3 feet.

(iii) One decontamination reduced these values to $\frac{1}{3}$ approximately.

SECTION VIII - THE ARMAMENT

APPENDIX C

The following defects were discovered on M.1 S.T.A.A.G. as a result of pre-wetting after Operation Mosaic.

1. Cathode Ray Unit Design 22(C.O's Display) requires replacement. Interior badly corroded and components rendered U/S due to sea water. (N.B. This is a Patt. Number article).

2. Mirror motor supply cable - full earth negative 220v D.C. supply load. Flexible cables on aerial unit corroded and damaged - require replacements.

3. Gaskets on covers of Range Follow Up and Blower Unit cubicles perished - require renewal.

4. All five in number multicore cables entering C.O's display unit require to be renewed - insulation impregnated with salt and corrosion of cores has set in.

5. Terminal Block Assembly in cubicle G(C.O's Display Unit) badly corroded and insulation low due to immersion in sea water - requires renewal.

6. Both cables entering Range Follow Up Unit cubicle require to be renewed. Insulation impregnated with salt and corrosion of cores has set in.

7. Terminal Blocks in Range Follow Up Unit corroded due to immersion in sea water.

8. Water tight rubber protector on aerial over-load reset push on F.1 cubicle perished and leaking. Requires removal and renewal.

9. Aerial Unit A.P.E. badly corroded externally, particularly body of mirror motor and resolves. Requires removal for over-haul and examination.

10. Air shut-off flap in air ducting to cubicles F.1 and F.2 etc. seized, requires stripping for over-haul.

11. Gaskets on air duct joints perished - require renewal.

12. Indicated bearing from T.I.U. Earth on both fine and coarse chains.

13. Radar Cut-Out Switch on Bearing Indicator - Insulation defective.

15. Mounting illumination circuits - earth on all circuits.

16. Oil leaking into main junction box.

17. Auto acquisition - Servo Unit damaged by salt water.

18. Contant speed motor in Range Box has been immersed in sea water and has "earth" on all coils.

/19. Control Hunters....

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SECTION VIII - THE ARMAMENT

APPENDIX C (Continued)

19. Control Hunters (magslip) in Range Box have defects as in 18 above.

21. Lateral rate circuit - insulation zero.

22. Sight lamp supply cable - insulation low.

23. Verticle rate circuit - insulation zero.

24. Lateral scan circuit - insulation low.

25. Verticle lag - cable insulation low.
Gyro supply cables - insulation low.
Tacho Box Motor - cable insulation low.

26. Firing circuits - cable insulations all zero.

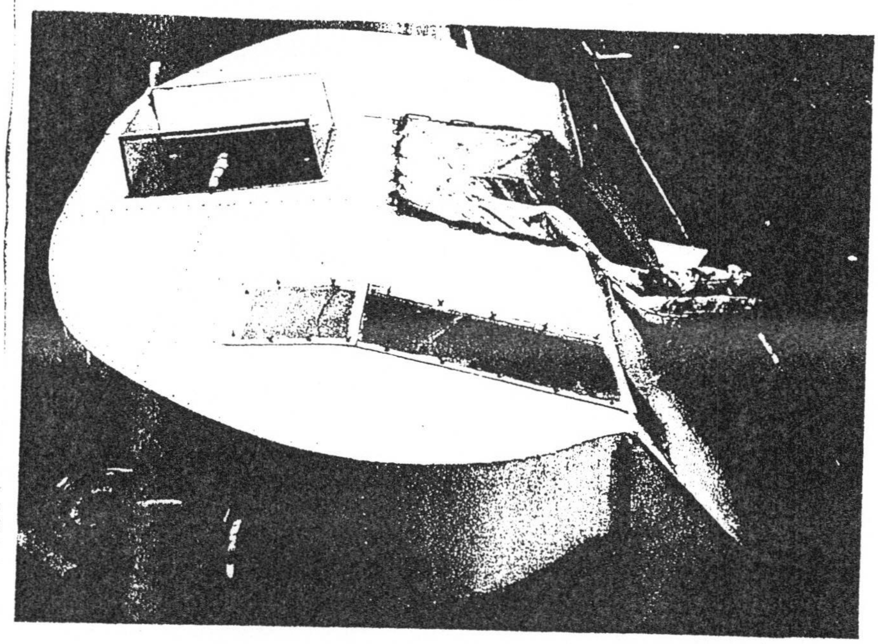
27. Aimers selector switch - cable insulations all zero.

28. Lateral lag (A.A.V) - cable insulations all zero.

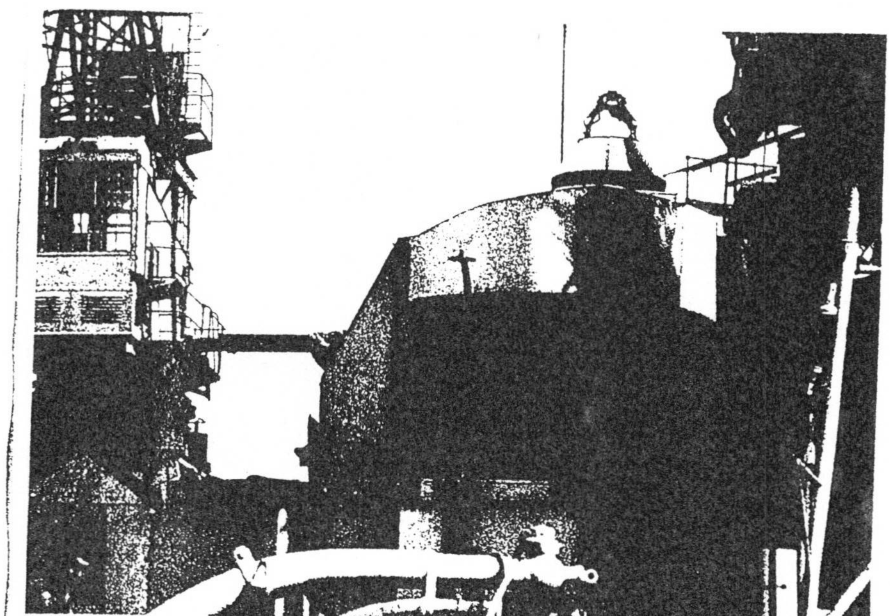
29. 60v. 60cycs. 3 phase supply - cable insulations all zero.

30. Tacho Box, junction box damaged by oil and sea water.

APPENDIX D to SECTION VIII

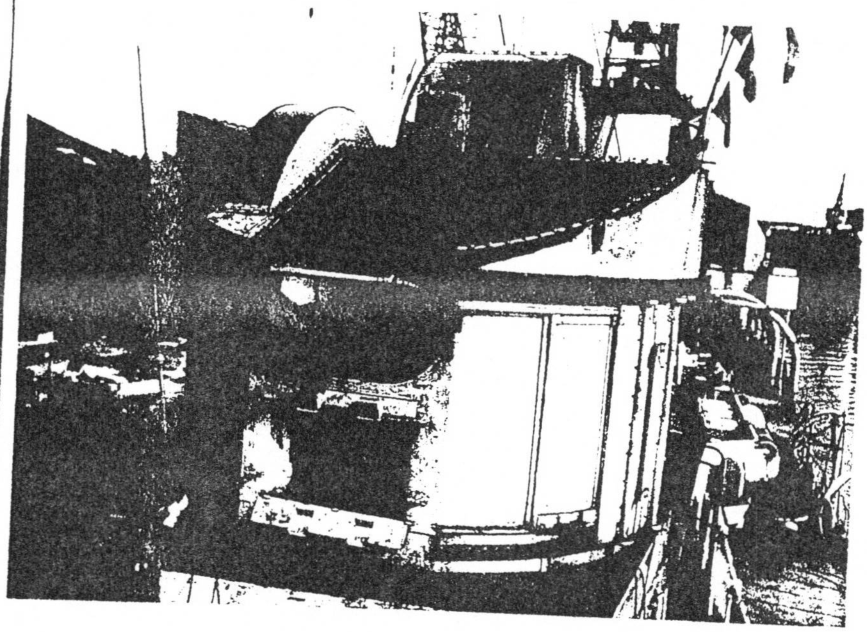


S.T.A.A.G.

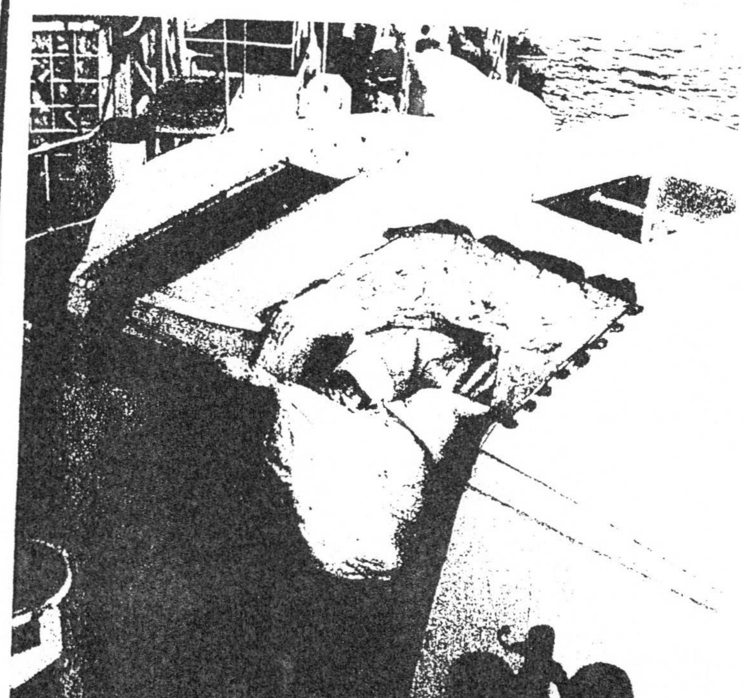


S.T.A.A.G.

APPENDIX D to SECTION VIII (



C.R.B.F.D. without canvas panel over the Radar Aerial (see text)



S.T.A.A.G.

SECTION IX - TRAINING

(i) General

Training for MOSAIC commenced after the ship had left Malta G.C. on Thursday, 12th April. The period before this, since commissioning on 28th February, was spent in post commissioning trials, including the special ones for the Operation, shaking down and painting ship.

2. Training was in general accord with the accepted principles (B.R. 1043(I), Chapter I), having as theme:-

(a) To achieve A.B.C.D. efficiency in the usually accepted sense.

(b) Then having slightly modified the drill: To meet the special requirements of Operation MOSAIC.

3. All departments concentrated on the ABC of ABCD to the practical exclusion of D and, in view of the nature and importance of the intended operation, key positions in the organisation were filled by the best available men without regard to their normal action billet. In practice this was not as serious as might appear and in the Post-MOSAIC adjustments only about ⅓ were changed. Against this must be set the fact that 32% of seaman junior ratings and 10% of engine room junior ratings were entered under the National Service Acts. In view of the scientific gear carried, none of the allowed complement of 16 Junior Seamen were carried.

(ii) Pre Commissioning Training

All men joined the ship having spent one week at the Devonport A.B.C.D. School.

2. Despite this it was necessary to embark on a heavy programme of lectures both on conventional A.B.C.D. lines and on radiation hazards by the Medical Officer in order to alleviate certain natural anxieties.

(iii) Departmental Training other Than Engine Room and Electrical

Besides the obvious requirements for A.B.C.D., some time was necessarily devoted to elementary weapon training, none with any remarkable result but enough to enable the ship to meet, in part, her basic committment as a Warship. This was kept to an absolute minimum for there were no facilities to hand, nor was there any prospect of a conventional work-up until September.

2. A detailed Training Programme forms Appendix "A" to this Section. This consists of a reproduction of the ship's relevant Weekly Training Programmes with suitable amplifying comments added.

3. As stated above, training started on 12th April and it was necessary to be ready by 2nd May, the day given by the Commodore Special Squadron as the earliest for the full dress rehearsal for HOTSHOT. This left 11 working days in which to prepare, of which 2 were devoted to Weapon Training and just over 2 to evolutions involving the whole Ship's

/Company . . .

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SECTION IX - TRAINING (Contd)

Company. To achieve the required result in the remaining 7 days involved much hard work especially when so much time was taken up with the working of the Special Boom for measuring water contamination. (See Appendix "B" to this Section).

4. Conventional evolutions such as Action Stations, Shelter Stations and Action Messing whether at Action or Shelter presented no difficulties. It should, however, be noted that even in a small ship of this class careful planning of the routes from Action Stations to Shelter Stations and back is a "must". As a yardstick, the best time taken to get from Action to Shelter Stations was 3 minutes 30 seconds in calm sea conditions. This time is entirely governed by the layout of the ladders leading down from the Bridge and Operations Room into the ship, bearing in mind the necessity of using as few screen doors as possible. The Shelter Station Bill and scheme of routes from Action Stations forms Appendix "C" to this Section.

5. All other aspects proceeded according to intention but very great difficulty was experienced in driving home to decontamination teams and, indeed, all others, the dangers of the ingestion of loose radioactive particles. This subject does not appear to be sufficiently emphasised in the A.B.C.D. Schools and is hardly covered in L.C.A.F.O's, (vide L.C.A.F.O. 117/55, paragraph 71). By the end of FLASHLIGHT it is believed that this lesson had been learnt.

6. Although all men came from Pre-Commissioning Training with some conception of the use of instruments to detect radiation and the "Roentgen", very little was known about the internal hazard from radioactive particles or about measures to detect or avoid it. Recommendations on this subject will be found in other sections of this report particularly concerned with the provision of suitable instruments, none of which exist in the Service at present, but it is considered appropriate here to stress the importance of proper training on this part of the subject. By the end of the Operation a large proportion had absorbed this lesson.

7. The following films were obtained on permanent loan:-

(a) Protection in Atomic Warfare, Parts 1 and 2.
(b) Medical Effects of the Atomic Bomb, Parts 1, 2 and 3.
(c) Industrial Radiological Decontamination of Ships - Ship Decontamination Methods.

Also whilst in Devonport, the film "A is for Atom" was taken on temporary loan from the A.B.C.D. School.

/8. Of these . . .

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Section IX - Training (Contd.)

8. Of these (a) Part 2 was found to be of the greatest value and was seen by the whole Ship's Company. Of the others it is not considered worth while using (b) for training purposes and although (c) was shown to all decontamination parties it was considered to be of rather academic interest.

9. C.B.(R) 4538B (A.B.C.D. Handbook for Daring Class) was found to be of little assistance in the preparation for Operation MOSAIC owing very largely to the considerable revision required. Two illustrations are given here and proposed amendments will be forwarded through the usual channels in due course.

(a) Chapter 10, paragraph 38.

Although the After Seaman's Bathroom is the best place from the point of view of size to have the ship's cleansing station, the main cleansing station must be forward in order to deal with the relief of Engine Room watchkeepers. (See Section IV of this Report).

(b) Plate 22

The construction of the ship does not in fact permit Gunbays or 4.5" Magazines to be part of the Citadel nor be gas-free spaces.

(iv) Recommendation

It is recommended that 7 working days be set aside for A.B.C.D. training in future working-up programmes if a satisfactory standard is to be attained.

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC

APPENDIX "A" - DETAILED TRAINING PROGRAMME

Weekly Training Programme No. 5

Week Ending Sunday, 15th April, 1956

Page of

11th April, 1956.

	Period "A"	Period "B"	Period "C"	Period "D"	Period "E"	Period "F"
	0945-1015	1045-1115	1115-1145	1430-1500	1515-1545	Dog Watches
(Thursday, 12th April)	Starboard Watch of Seamen to A.B.C.D. Lecture by First Lieutenant.	Port Watch of Seamen to A.B.C.D. Lecture by First Lieutenant.	Boarding and Search Parties muster on the F.X Fit Equipment. Lt. Cdr. (G).	Communications Division to ABCD Lecture by First Lieutenant. Central Division to ABCD Lecture by Lt. Cdr. Mallory. (Neg.. Maltese)	All First Aid Parties muster in the Sick Bay for Lecture by Medical Officer. Monitoring Teams muster for Lecture. Lt. Cdr. Mallory.	A.B.C.D. Films
(Friday, 13th April)		Port Said Suez Canal		All Maltese Ratings to ABCD Lecture by Lt. Cdr. Mallory.	Decontamination Parties to Lecture by Lt. Cdr. Mallory	NIL
(Saturday, 14th April)	Messdeck Rounds (During Rounds - 1 Platoon Fit Equipment			NIL	NIL	A.B.C.D. Films 1630 Action Stations. Shelter Stations
(Sunday, 15th April)	NIL	NIL	NIL	NIL	NIL	NIL

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC
APPENDIX "A" - DETAILED TRAINING PROGRAMME (Contd)

Weekly Training Programme No. 6

Week Ending Saturday, 21st April, 1956

1[illegible]th April, 1956

	0915-1015	1030-1140	1330-1430	1440-1545	Dog Watch
Monday, 16th April	(1) "A" Turret Crew to Drill. (2) D.C. Communication No's to Drill. D.C.H.Q. Required.	(1) D.C. Parties close both Citadels. (2) First Air Parties mustrat Sick Bay. (3) Scientific Parties muster in Scientific Centre.	(1) 4.5" Control Parties (2) Ops Room Crew detailed.	(1) "B" Turret Crew to Drill.	Evening Quarters.
Tuesday, 17th April	AT ADEN				
Wednesday, 18th April	(1) "A" Turret Crew to Drill. (2) Rig Decontamination Bathroom.	1100 Action Stations D.C. State 1A. Shelter Stations. Monometers to be rigged.	1315 Secure from Action Messing. 1330 Both Watches of the Hands fall in.	(1) 4.5" Control Parties. (2) 1440-1510 "B" Turret Crew. (3) 1510-1545 "X" Turret Crew. (4) Ops. Room Crew as detailed.	NIL Evening Quarters.
Thursday, 19th April	(1) F.A.P's muster in S.B. (2) Monitoring Parties muster at Staff Office. (3) D.C. Communication NO's to Drill.	(1) Decontamination Parties to muster Port Break of the Foc'sle. (2) Scientific Parties muster in S. Centre.	NIL	M.1, M.2 and M.3 to Rapid open Fire Exercise on Smoke Bursts fired by "X" and "B" Turrets.	NIL

/Friday, 20th April . . .

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC
APPENDIX "A" - DETAILED TRAINING PROGRAMME (Contd)

Weekly Training Programme No. 6 (Contd)

	0915-1015	1030-1140	1330-1430	1440-1545	Dog Watch
Friday, 20th April	0915 1 Platoon Muster. Board and Search Parties muster.	(1) Decontamination, Scientific, D.C. Parties muster on "B" Gun Deck. (Reporting Procedure)	1330-1400 "A" Turret Crew. 1400-1430 "X" Turret Crew.	Torpedo Firing Exercises	NIL
Saturday, 21st April	CAPTAIN'S MAGAZINE AND STOREROOM ROUNDS		NIL	NIL	Evening Quarters

NOTES:

Thursday, 19th April

(a) Monitoring parties closed up with instruments in their assinged areas. Radioactive sources had been placed around the ship - thus men learned the use of instruments, reporting procedure and confirmed in their minds the detailed configuration of the ship.

(b) Decontamination parties fitted protective clothing and in a conducted tour of their areas had the likely "hot spots" indicated to them.

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC
APPENDIX "K" - DETAILED TRAINING PROGRAMME (Contd)

Weekly Training Programme No. 7

Week Ending Saturday, 28th April, 1956

20th April, 1956

	0915-1015	1030-1140	1330-1430	1440-1545	Dog Watches
Monday, 23rd April	AS PIPED: Action Stations Damage Control State 1A. Rig Pre-wetting. Shelter Stations. Decontamination Parties. Monitoring Team.		Air Monitoring Team muster in the Scientific Centre. (Mr. Thomas).	1445 Decontamination Parties to film "Decontamination of Ships" in For'd Mess Deck.	NIL
Tuesday, 24th April	(1) Monitoring Parties muster at A.B.C.D. H.Q. (2) Prize Crew muster on the Foc'sle - Fit equipment.	1030-1110. F.X., Top and TAS Divisions muster in Communications and Electrical Messdeck. (Talk by Doctor). 1115. Rig both Cleansing Stations.	1330-1400 For'd Cleansing Party close up. 1400-1430 After Cleansing Station Party close up.	1440 - All Damage Control Communication Numbers close up on "B" Gun Deck. (Mr. Thomas)	EVENING QUARTERS (Boarding Party Search Party) 2nd M/C Required
Wednesday, 25th April	(1) Monitoring Parties muster at A.B.C.D. H.Q. (2) Rig Pre-wetting. (3) Rig Special Canvas gear. (4) Rig Fx'le Awning.	Air Monitoring Team muster in the Scientific Centre. (Mr. Thomas). 1030-1110. Gunnery, Central and Q.D. Divisions muster in communications and Electrical Messdeck. (Talk by Doctor)	MAKE AND MEND CLOTHES		Action Stations Damage Control State 1A. MOSAIC Procedure (Net. Boom) Action Mess Supper at Shelter Stations.

/Thursday, 26th April . . .

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H.M.S. DIANA's REPORT ON OPERATION MOSAIC
APPENDIX "A" - DETAILED TRAINING PROGRAMME (Contd.)

Weekly Training Programme No. 7 (Contd)

	0915-1015	1030-1140	1330-1430	1440-1545	DOG WATCHES
Thursday, 26th April					
0800 Arrive Channel leading to Singapore.		NIL	BOARDING AND SEARCH PARTIES LAND TO SMALL ARMS RANGE		NIL
Friday, 27th April			IN SINGAPORE		

NOTES:

Monday, 23rd April

This was the first occasion with all teams closed up together, monitoring parties practising with radioactive sources, and decontamination with protective clothing and "web" hoses.

Tuesday, 24th April

(a) Monitoring teams had further practice on searches for radioactive sources and in using the correct reporting procedure.
(b) Cleansing and undressing station crews closedup and went through the full drill of undressing, monitoring simulated contaminated personnel some of whom had radioactive buttons concealed on their person.

Wednesday, 25th April

As for Tuesddar, 24th April, (a) above.

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APPENDIX "A" - DETAILED TRAINING PROGRAMME (Contd)

Weekly Training Programme No. 8

29th April, 1956

Week Ending Saturday, 5th May, 1956

Monday, 30th April

0915 - 1035 — Air Monitoring Parties muster in Scientific Centre.

Tuesday, 1st May — SHIP'S REHEARSAL - FIRST LIEUTENANT MEMO No. 33 WILL BE ISSUED GIVING TIME TABLE OF EVENTS.

Wednesday, 2nd May

0800 — ARRIVE MONTE BELLO

NIL

Thursday, 3rd May

1030-110 — E.R. & "L" ratings detailed and Communications Division muster in Communication and Electrical Messdeck (lecture by Doctor).

DOGS — Evening Quarters.

Friday, 4th May — TO BE ISSUED LATER.

Saturday, 5th May — TO BE ISSUED LATER.

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SECTION IX - TRAINING

APPENDIX B

SPECIAL TOWING SPAR FOR WATER-MEASURING GEAR

A special boom, spar and equipment were fitted in H.M.S. DIANA in Devonport to house scientific water-measuring instruments for the Special Trials.

2. These were first tested during the ship's post-refit sea trials. Unfortunately during these trials the spar was bent by paravaning into the side of the ship. It was, however, repaired before leaving Devonport, and the length of the towing spans were increased by 20 feet, as is had been discovered that these were too short and had caused the sheer. The spar was next towed off Gibraltar on the 7th April, when it streamed without mishap, though the lower end still tended to sheer towards the ship.

3. Whilst on passage to Singapore it was realized that a small boom for carrying the cables from the top of the towing spar into the Scientific Centre had been omitted from the specifications in Devonport. This was constructed in Singapore to drawings by ship's officers.

4. During the Dress Rehearsal for MOSAIC on the 5th May the spar was streamed satisfactorily for two hours: at the end of this time however, it buckled and had to be recovered. This buckling was not due to contact with the ship's side, but to its being too weak to stand the stresses and strains of a tow of long duration.

5. The bent spar was repaired, and both spars strengthened, during the ship's visit to Fremantle. On testing again, however, it was found that the additional weight of the strengthening (42.75 lb) had upset the buoyancy of the spar, and it no longer streamed vertically.

6. Despite this, it was decided to use the spar for the operation, but when the time came to insert the instruments into it, it was found that the tube through which the cables were to pass was filled with tightly packed buoyancy material. In view of the spar's past record, and its increased weight, it was not considered acceptable to clear the channel.

7. A jury rig was therefore devised, and the instruments were streamed from the small boom fitted in Singapore, on a 1½-inch wire, weighted with a ½-cwt sinker. At speeds below 4 knots the wire was as near vertical as to enable readings to be taken as though from the spar. This method was used during both HOTSHOT and FLASHLIGHT and proved quite satisfactory.

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FORWARD CITADEL

No of Shelter Station.	Position of Shelter Station.	Action Quarters.	Approx. No's.	Approx. Total.
1	FOR'D STWD'S & COOKS MESSES. No. 3 DECK.	ACTION MEDICAL PARTIES FOR'D. DECONTAMINATION PARTIES FOR'D. "A" TURRETS CREW.	5 2 21	28
2	FOR'D M(E's) MESSDECK. No.3 DECK.	FOR'D REPAIR & FLOODING PARTIES. M.2 S.T.A.A.G's CREW. A.1. MAG. CREW. A.2. MAG. CREW.	30 8 2 2	42
3	W/K's MESSDECK & POM(E's) MESS.	"B" TURRETS CREW. B.1. MAG.CREW. M.1. S.T.A.A.G's CREW. COMMS. RATINGS.	21 2 8 9.	40
4	PETTY OFFICERS MESS. No.3 DECK.	A.C.R's CREW A/S. FOR'D TUBES CREW. TORPEDO CONTROL. A.S. ROOM CREW. WHEELHOUSE CREW. Mk.6 DIRECTORS CREW. BRIDGE LOOKOUTS. SIGHT OPERATOR ACTION BOSUN'S MATE. T.I.U's CREW.	7 9 2 3 4 4 1 1 3	33 (S.U) or 3[illegible] (A.S)
5	FOR'D AUX.MACH. SPACE No.3 DECK.	T.S. & F.P. CREWS. FOR'D SWITCHBOARD. MAIN W/T. OFFICE CREW. V.H.F. OFFICE CREW. "A" BOILER ROOM CREW.	13 4 6 3 4	30

"A" ENGINE ROOM. Shelter Station	"B" BOILER ROOM Shelter Station.
No.6.	No.7.
SPECIAL ENGINE ROOM SHELTER STATION CREWS. APPROX. No. 8.	SPECIAL BOILER ROOM. SHELTER STATION CREWS. APPROX. No. 8.
"A" BOILER ROOM	**"B" ENGINE ROOM**
EVACUATE & PROCEED TO SHELTER STATION No. 5.	EVACUATE & PROCEED TO SHELTER STATION No. 9.

AFTER CITADEL

No.of Shelter Station.	Position of Shelter Station.	Action Quarters.	Approx. No's.	Approx. Total.
8	M(E's) MESS-DECK (AFT) No.3 DECK.	AFTER FLOODING AND REPAIR PARTIES. X.1 MAG. CREW.	30 2	32
9	C.P.O's & E.R.A's MESSES. No.3 DECK.	AFTER DECONTAMINATION PARTIES. X.2. MAG. CREW. X. TURRETS CREW. "B" ENGINE ROOM CREW.	3 2 21 4	36
	SEAMANS LOWER MESS-DECK (AFT). No.3 DECK.	M.3 BOFORS CREW. C.R.B.F.D. CREW. No.2 W/T ROOM CREW. AFTER SIGNAL POS'N. AFTER TUBES CREW (S.U). AFTER TORPEDO CONTROL. (S.U) SQUID CREWS (A.S) AFTER STEERING POSITION. ACTION MEDICAL PARTIES AFT. TILLER FLAT.CREW. AFTER SWITCHBOARD CREW.	7 3 4 2 6 8 5 3 3	

Note:- Captains of Turrets are responsible for closing Gun Bay Access Doors.

copy No. 15

ROUTES TO SHELTER STATIONS (FOR'D CITADEL)

No. of Shelter Station	Action Quarters	Route from Action Quarters to Shelter Station
1.	Action Medical Party (For'd).	From Wardroom - Hatch to Staff Office Flat via Cross passage - Forward via Port Passage and Messdecks to Shelter Station.
	Decontamination Parties For'd.	Forward from Canteen Flat, through Port side of Messdecks to Shelter Station.
	"A" Turrets Crew.	Down Gunbay via Access Door to Messdeck - Forward via Messdeck to Shelter Station.
2	For'd Repair & Flooding Parties.	For'd from Canteen Flat via Port side of Messdecks to Shelter Station.
	M2 S.T.A.A.G's Crew.	Forward via Port Access Door from upper deck, Port Passage and Messdecks to Shelter Station.
	A1. Mag. Crew. A2. Mag. Crew.	Up from Mag. Close down to Shelter Station.
	"B" Turrets Crew.	Down to gunbay, down ladder to Canteen Flat - via Stb'd. Door to Messdeck Hatch to Shelter Station.
3	B.1 Mag. Crew.	Up from Mag. Close down to Shelter Station.
	M.1 S.T.A.A.G's Crew.	Forward via Stb'd. Access Door from upper deck, Stb'd Passage & Messdeck to Shelter Station.
	Communications.	Down Hatches from Bridge, Flag Deck & M.S.O. - Forward via Stb'd Passage, Canteen Flat and Hatch to Shelter Station.
4	A.C.R's CREW (A/S). TORPEDO CONTROL (S.U).	Down Hatches, For'd via Starboard Passage, Canteen Flat and hatch to Shelter Station.
	For'd Tubes Crews.	For'd through Port Port Access Door from Upper Deck via Port Passage, Canteen Flat and Hatch to Shelter Station.
4	Ops. Room, Wheel House & T.I.U's Crews.	Down Hatches to Stb'd Passage - Forward via stb'd Passage to Canteen Flat - Hatch to Shelter Station.
	Bridge Look-Outs, Mk.6 Directors Crew.	Down Hatches to Starboard Passage, For'd through Starboard Passage to Canteen Flat, Hatch to Shelter Station.
	B.2. Mag. Crew.	Up from Mag. Close down to Shelter Station.
5	T.S. & F.P. Crew	Remain in T.S. & F.P. Compartment.
	For'd Switch-Board Crew.	Remain in Switchboard.
	Main W/T. Office.	From W/T. Office, down hatch in Cross Passage to Shelter Station.
	"A" Boiler Room Action Crew.	Up Hatch from "A" Boiler Room - Cross Passage down Hatch to Shelter Station.
	V.H.F. Office Crew.	Through Port Access Door from upper deck, Down Hatch to Shlter Station.

Notes:- POSITIONS OF ACCESS DOORS ARE TO BE USED AS FOLLOWS:

(a) DOOR LEADING FROM UPPER DECK TO STARBOARD PASSAGE BY BREAK OF FORECASTLE.

(b) DOOR LEADING FROM UPPER DECK TO PORT PASSAGE BY BREAK OF FORECASTLE.

(c) DOOR LEADING FROM FLAG DECK STARBOARD SIDE INTO M.S.O. FLAT.

COPY No.15

ROUTES TO SHELTER STATIONS (AFTER CITADEL)

No. of Shelter Station.	Action Quarters.	Route from Action Quarters to Shelter Station.
6	"A" Engine Room.	Special A.B.C.D. Shelter Station. Crew remain at Quarters.
7	"B" Boiler Room.	" " " " "
8	After Repair & Flooding Partiss (Aft).	Down Hatch to Shelter Station.
	X.1 Mag. Crew.	Up from Mag. Close down to Shelter Station.
9	After Decontamination Party.	Down Hatch to Shelter Station.
	"X" Turrets Crew.	Down to Gunbay, via Access Door to Sick Bay Flat. Aft to hatch and Shelter Station.
	"X.2" Mag.Crew.	Up from Mag. Close down to Shelter Station.
	"B" Engine Room Crew.	Up from "B" Engine Room - Aft to Hatch and Shelter Station.

No. of Shelter Station.	Action Quarters.	Route from Action Quarters to Shelter Station.
10	M.3 Bofor Crew.	
	C.R.D.F.D. " After Signal Position. After Steering After Torpedo Control.	Aft along Catwalk to "X" Gundeck. Down ladder through Access Door on Quarterdeck - via hatch to Shelter Station.
	Squid Crew A/S. After Tubes Crew No.2 W/T Room Crew.	In through Access Door, via hatch to Shelter Station.
	Tiller Flat Crew.	Up from Tiller Flat - through Access Door via hatch to Shelter Station.
	Medical Parties (Aft).	From Sicj Bay to Hatch and Shelter Station.
	After Switch-Board Crew.	Remain at Switchboard.

Notes:- POSITIONS OF ACCESS DOORS TO BE USED ARE AS FOLLOWS:

(a) DOOR FROM QUARTERDECK INTO PASSAGE.

(b) DOOR FROM IRON DECK, ADJACENT TO AFTER TUBES INTO SICK BAY FLAT.

COPY No.15

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SECRET U.K. EYES ONLY

SECTION X - COMMUNICATIONS

(i) No communication difficulties were experienced during HOTSHOT or FLASHLIGHT.

(ii) A listening watch was kept on the following frequencies from 15 minutes before the burst until after fallout had ceased. No abnormalities were observed.

U.H.F.	277.8 mc/s.	
	280.0 mc/s.	
V.H.F.	136.44 mc/s.	(see note)
	107.46 mc/s.	
	149.76 mc/s.	
H.F.	16 mc/s.	Broadcast components.
	12 mc/s.	
	8 mc/s.	
	6 mc/s.	
	4 mc/s.	
	500 kc/s.	

(iii) Communication on 4236.5 kc/s with remainder of squadron was maintained loud and clear (using type 602 with wire aerial) throughout both HOTSHOT and FLASHLIGHT.

Note:- Aircraft transmitting on 136.44 were observed to fade completely when passing into the atomic cloud immediately after the burst, and become loud and clear having passed through and emerged on the other side. This only ocurred IMMEDIATELY after the burst, i.e. before the cloud began to disperse.

(iv) Office Conditions

In order to increase fire main pressure, air conditioning in the Main Wireless Office was switched off for the greater part of the time during which A.B.C.D. State 1A was in force.

2. Without air conditioning and with prolonged use of transmitters (types 603 were not used in HOTSHOT or FLASHLIGHT) it is likely that material damage would result due to heat and humidity.

3. Under conditions prevailing in the Main Wireless Office one hour after closing down i.e. air conditioning off, cypher machines type TSEC-KL7 became mechanically unreliable.

4. Heat in the 2nd W/T Office caused breakdown in insulation in type 6?8 rectifier and power unit.

5. The Main W/T Office is the only office which can be manned in A.B.C.D. State 1A, the 2nd, 3rd and U.H.F. Offices being outside the citadels.

V.S.

Flag lockers were cleared during HOTSHOT and FLASHLIGHT. It is considered that flags would become sufficiently contaminated if left stowed that they would have to be disposed of. In any event, the canvas locker covers have to be destroyed, and it is recommended that some other non absorbant material (polythene) be used instead of canvas for this purpose, giving greater protection to the contents of the locker and which can be decontaminated by hosing down.

Copy No. 15

NUCLEAR EXPLOSIONS
OPERATION MOSAIC

EFFECT OF FALLOUT ON MACHINERY SPACES

REPORT OF TRIALS IN H.M.S. DIANA

[illegible] C. [illegible] HALLIFAX

IMPORTANT
Attention is drawn to
the provisions of the
Official Secrets Act

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W 382

REPORT NO. 4646R.
SEPTEMBER 1956.

NUCLEAR EXPLOSIONS, OPERATION MOSAIC. EFFECT OF FALLOUT ON MACHINERY SPACES. REPORT OF TRIALS IN H.M.S. DIANA.

ABSTRACT

[During the atomic weapon tests at Monte Bello in May and June 1956 (Operation MOSAIC), in which H.M.S. DIANA participated as 'Fallout Observation Ship', opportunity was taken to conduct a number of ad-hoc trials to investigate the radiological hazards caused by fall-out to machinery spaces and machinery.

Owing chiefly to the paucity of fallout encountered, these trials were not all successful, but a number of important conclusions can be drawn from those that were, and a large number of lessons learnt for the future.]

The principal conclusions are:-

1. That fall-out can and will enter the intakes of boilers and of running ventilation systems in large quantities, of which very little if any leaves the ship.

2. That the resulting contamination is mainly loose, that is, easily transferred to the lungs and stomach, and must therefore be considered a hazard even though the external dose rate is very low. No test equipment is in service, and little doctrine exists on this hazard.

3. Proper decontamination of machinery spaces is impracticable.

4. Seawater contamination from fall-out may linger at or near the surface for some time. It is therefore impracticable to avoid all contamination of evaporators in existing ships simply by stopping them whenever fall-out is suspected.

Of the lessons learnt, a number concern the operation of Radiac Instruments under more or less action conditions, and may therefore be considered important for the future. Others concern the conduct of any similar operations in which contamination may be encountered, and may therefore be important for any ships supporting atomic weapon tests in future, in whatever capacity.

J Halifax
11th September 1956.

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3 - Arrangement of samples in blower rooms and intakes - HOTSHOT.
4 - " " " " " " " " - FLASHLIGHT.
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6 - " " " " " " - side casing.
7 - " " " " " " - bottom casing.
8 - " " " " " " - front casing.
9 - Arrangement of plates in uptakes and funnel.
10 - Arrangement of brick samples in furnaces.
11 - Engine room ventilation systems, showing sample positions.
12 - Arrangement of plates around diesel alternator.

1. INTRODUCTION - OBJECTIVES.

1.1. During the atomic weapon tests at Monte Bello in May and June, 1956 (Operation MOSAIC), in which H.M.S. DIANA participated as 'Fall-out Observation Ship', the opportunity was taken to carry out a number of ad-hoc trials in the machinery spaces and machinery.

1.2. This report deals only with radiological trials carried out in the machinery spaces and machinery. Tests of protective clothing, habitability under closed-down conditions, the prewetting system and many other trials, are fully documented in "H.M.S. DIANA'S report on Operation MOSAIC". Details of other radiological tests, including some of the test results on which this report is based, will be found in the report of the scientific team from the Admiralty Research Laboratory.

1.3. The object of the trials under report was three-fold, viz:-

1. To discover and evaluate, as far as possible in a single operation, what hazards if any to engineering personnel are to be expected as a result of passage through fall-out from atomic weapons, and to assess their effect on the operation of the machinery.

2. To ascertain whether, and if so to what degree, the behaviour of fall-out can be simulated by non-radioactive tracer, by investigating the correlation if any between the deposition of active material in H.M.S. DIANA'S boilers and the deposition of chemical tracer observed in trials previously carried out in a sister-ship, H.M.S. DECOY. (E-in-C. report 5086.R (A.R.L. report ARL/R.1/C758) dated April 1956).

3. To obtain experience in the organisation and conduct of trials of this nature, for the benefit of any future trials which may be envisaged.

In view of objective 3 above, this report is of necessity rather more detailed than would otherwise have been desirable. It is hoped, however, that sufficient summaries have been provided to avoid the worst effects of this.

1.4. It must be emphasised that the primary object of H.M.S. DIANA's participation in the operation was to enable a scientific team from the Admiralty Research Laboratory, Teddington to make observations and records of the fall-out itself, and that the conduct of the trials under report was at all times subordinated to this object. This, combined with the fact that very little time was available either for preparation or training, may serve to explain some of the more obvious deficiencies in the arrangements for and conduct of these trials.

SUMMARY

2.1 Outline of the Trials

2.1.1 Operation MOSAIC involved the firing of two weapons, referred to at the time (and, for convenience, throughout this report) as "HOTSHOT" (fired on 16th May) and "FLASHLIGHT" (fired on 19th June). For each shot, the movements of and conduct of trials in H.M.S. DIANA were similar. The ship was placed so as to receive what was hoped would be a sufficient but not excessive amount of fall-out, and was to steam from this position at a suitable course and speed for efficient pre-wetting.

2.1.2 Arrangements were made in the machinery spaces which it was hoped would yield information on the following subjects:-

a) Dose-rates due to any deposited fall-out in all parts of the machinery spaces in use ('A' Engine Room and 'B' Boiler Room), particularly in the neighbourhood of machinery such as the boiler, condensers, evaporator, etc., which might become contaminated internally.

b) Transit doses in positions normally occupied by watchkeepers.

c) Contamination of ventilation air, and contamination of spaces as a result.

d) Contamination of evaporators and their output, and the effect of subsequent blowing down.

e) Contamination of diesel engines and the effects of any leakage from cylinder head gear.

f) Shielding factors in machinery spaces, both from upper deck contamination and from contaminated machinery.

g) Contamination of condensers and sea-water systems.

h) Position and extent of deposits of active material in the air/gas path of the steaming boiler.

i) The relation between air contamination outside the ships pre-wetting system, that entering ventilation and boiler air systems and that leaving ventilation exhausts and funnels.

2.1.3 It was intended that the fall-out encountered should be such as would give a dose of 5R (to infinity) to an observer on an exposed horizontal plane. In the events, the extent and intensity were far below this. Levels were apparently about one twenty-fifth of that intended in both events. This, together with the fact that active sea water was occasionally found without any airborne fall-out (indicating that fall-out had occurred previously in those positions) causing the ship to contaminate herself by the pre-wetting, caused many of the tests to be fruitless. Some of the trials had to be abandoned. Sufficient data was gathered, however, from the remainder for a number of lessons to be learnt, and some worthwhile conclusions drawn. In the main, these conclusions are purely qualitative, though some very approximate quantitative estimates have been made.

2.1.4 In view of objective 3 (para. 1.3 above) of the trials, which was to obtain experience in the organisation and conduct of such tests, this report contains reasonably complete details of all tests arranged, and of their conduct in the events, whether or not any useful results were obtained. This has unfortunately resulted in a rather lengthy report, but it is felt to be justified as the details

/given

given may well be of use in planning any future series. In most cases the only reason for failure was absence of sufficient fall-out. In some cases, better instrumentation would have produced results, and in these cases appropriate suggestions have been made.

2.1.5 All conclusions and suggestions for future tests are given at the end of each section, and are also collected together in Section 10 of the report. A number of these are of wider application than to Engineering trials and hazards, and have in a few cases been reported elsewhere. This report would not, however, be complete without them. A number of relatively minor points, chiefly concerned with radiac instruments and their use, has also been included. It is felt that this is justified by the fact that, so far as is known to the writer, operation 'MOSAIC' was the first opportunity for the Service users to obtain practical experience of this type under something approximating to service conditions.

2.1.6 Since therefore the conclusions in Section 10 are many in number and cover a wide range of importance, those which are of the greatest importance have been abstracted and are shewn in Section 2.2 below.

2.2 Principal Conclusions

2.2.1 The first conclusion to be drawn from these trials is that airborne fall-out can and will enter protected intakes through pre-wetting. The amount entering is apparently liable to be virtually all that exists outside the pre-wetting, and may in effect be very much more, if contaminated seawater is used for pre-wetting.

2.2.2 Of that which enters either boiler or ventilation air systems, virtually none can be expected to leave the ship. An approximate distribution of deposits as proportions of the total entry might be:-

Boiler System

Blower Rooms and intakes: 35-45%
Furnace Brickwork: up to 25%
Tube nests: 30-50%
Air casings: Trace, say 1%
Uptake and Funnel: Trace, say 2% (in soot)

Ventilation System

Supply fan and trunking: 35-45%
Space ventilated: about 45%
Exhaust fan and trunking: about 10%

2.2.3 Sootblowing can be expected to reduce the boiler tube contamination, though apparently not by more than about 50% even if repeated. Great care would clearly be required when blowing soot for this purpose under war conditions.

2.2.4 Of the contamination deposited, the majority is "loose" in the sense that it can easily be inhaled as dust, or ingested via the hands and mouth. This can be a serious hazard even though the quantity is minute, far too little to show an appreciable gamma dose-rate externally.

2.2.5 For this type of contamination there is neither adequate detection equipment nor doctrine as to acceptable risks in Service.

2.2.6 Neither machinery spaces nor the insides of boilers can be decontaminated effectively. This, combined with the very extensive effects of the necessary health precautions on normal operation and maintenance, make it essential to avoid contamination by any means possible.

2.2.7 It is apparent that fall-out lingers in considerable quantities at or near the sea surface for some time after the event, to be dispersed by winds and currents. This makes it impracticable to rely on avoiding contamination by stopping evaporators during fall-out.

/ 2.2.8

2.2.8 The question of contamination of distillate is therefore raised. Neither equipment nor doctrine for this is at present generally available.

2.2.9 No tests of evaporator carry-over could be made as no equipment was available for testing drinking water to the required tolerance, but it was evident that there is a need for all ships supporting atomic weapon tests in future to carry such equipment.

2.2.10 Correlation between the boiler trials and the chemical tracer trials in H.M.S. DECOY was remarkably good, but there are still several trials required which it does not appear can be carried out with simulants.

3. NARRATIVE.

3.1. General. - Basic Scheme.

3.1.1. It is not intended to give here the full narrative of H.M.S. DIANA's participation in Operation MOSAIC. In order to view the trials under report and their results, or lack of them, in perspective, it is however necessary to outline the sequence of events during each phase of the operation.

3.1.2. The conduct, from the aspect of machinery operation and trials, of both phases of the operation was generally similar, the basic scheme being as follows:-

a) On the day of firing the ship steamed from Monte Bello to a position determined, on a basis of weather reports and the expected yield of the weapon, by the A.W.R.E. staff in H.M.S. NARVIK. This passage was expected to and did in fact require speeds between 20 and 27 knots. The predicted position was subject to alteration at any time before or during fall-out.

b) On arrival in position, the ship turned into the wind, and the Port engine was stopped and shaft disconnected. 'A' Boiler was shut down, and all machinery in 'A' Boiler Room and 'B' Engine Room, other than that required for prewetting or for the safety of the still-warm Port engine, was stopped. .

c) As late as could safely be arranged before the arrival of fall-out, all ventilation to machinery spaces was stopped and the ventilation flaps on supply and exhaust terminals shut. Canvas flaps were dropped over the air intakes to 'A' Boiler, and the forward funnel cover was hoisted. The exhaust flaps from 'B' Boiler Room into the uptake space were not closed, as it would have been almost impossible to open them quickly in an emergency, and after consultation with the Operation Health Physics Controller it was thought most unlikely that any active material would descend into the boiler room past the funnel bonnet and this space, particularly against the up-draught from the heated space below.

d) As the machinery space ventilation was closed down, the watch-keepers in 'A' Engine Room and 'B' Boiler Room were relieved by a skeleton watch wearing experimental air-ventilated suits for protection against temperature conditions. 'A' Boiler Room and 'B' Engine Room were evacuated, and all access hatches closed. Some photographs of the air-ventilated suits in use are shown in Fig.1.

e) For the next two to two-and-a-half hours the ship was steamed in this fully closed-down state. At the end of this time, the supply of air-ventilated suits being exhausted, a special party in protective clothing and respirators opened the ventilation supply systems to 'B' Boiler Room, and the forward supply and exhaust systems to 'A' Engine Room, and started the appropriate fans. The watchkeepers were then relieved by others wearing special protective overalls (loaned by A.W.R.E.) and anti-gas respirators.

f) From this time until fall-out ceased and/or the search for more was abandoned, the machinery was operated by watchkeepers in the A.W.R.E. suits, with the limited ventilation described above. In the case of 'A' Engine Room, this was half the full ventilation, the systems used being chosen for the protected nature and position of the intake and exhaust terminals. In

/the ....

the case of 'B' Boiler Room full ventilation was used, there being no difference between the two intakes, which at first sight appear well screened, but as a measure of additional protection a canvas screen was placed at the Starboard end of the Boiler Room cross-passage in which the intakes are sited. The Port end of this cross-passage was left open, to avoid interference with the trials being carried out on the boiler intake. (See Section 6.) In Operation 'FLASHLIGHT', this screen was not fitted, owing to a last-minute change of timing, which caused the whole machinery shut-down to be carried out as an evolution.

3.1.3. The arrangements for trials are described in later sections of this report, and its Appendices. At this stage it is sufficient to record that readings of dose-rate meters and total dose instruments were taken in various positions in the spaces in use at intervals throughout each operation, that air samples were taken while the ventilation was open at intervals whenever airborne fall-out was suspected to be present, and that a thorough monitoring survey was carried out immediately on conclusion of each trial.

3.1.4. Very nearly all the special radiac equipment and instruments used for these trials was supplied by the Scientific Staff from the Admiralty Research Laboratory. In addition to this, the work of testing samples was carried out by Mr. D. M. C. Thomas, Senior Scientific Officer, of A.R.L., and his colleagues, from whom were obtained the great majority of the test results on which this report is based.

3.2. <u>Operation 'HOTSHOT'</u>.

3.2.1. This first shot was fired at 1151 (local time) on 16th May. H.M.S. DIANA was stationed approximately 40 miles from "ground zero". The ship was closed down fully by 1300, and very faint traces of fall-out were detected at 1305.

3.2.2. Unfortunately, the fall-out predictions were wrongly based, and very little was encountered, even though course and speed were adjusted several times in search of it. The ship was for the most part steaming through seawater contaminated from past fall-out, at speeds varying from 2 to 15 knots. Airborne fall-out was found only from 1325 to 1330, and again from 1910 to 2100.

3.2.3. The search was abandoned at 2130, and monitoring of the upper deck started at once. Machinery space ventilation flaps were decontaminated, and ventilation to all machinery spaces was restored by 2300, by which time also the canvas screens had been removed from 'A' boiler intakes and the forward funnel cover lowered.

3.2.4. The Port engine was reconnected by midnight, and at 0230 on the 17th, 'A' Boiler was connected and 'B' Boiler at once shut down, reducing the watch necessary in the contaminated boiler room to those needed for the turbo-alternator and the evaporator. 'B' boiler remained shut down, mainly for operational reasons, until the ship left Singapore on June 3rd.

3.2.5. Details of subsequent monitoring, decontamination and other precautions are given later in the appropriate sections of this report. It is therefore sufficient here to record that:-

a) 'A' boiler room and 'B' engine room had become lightly contaminated (on the decks only) by transfer on boots and shoes. They were declared "clean" by H + 28 hours.

/ b) .....

b) 'A' engine room and 'B' boiler room were generally and more heavily (though still in terms of operational contamination very lightly) contaminated throughout. These spaces were partially decontaminated. 'A' engine room was declared "clean" for normal watchkeeping duties at H + 48 hours, and 'B' boiler room similarly at H + 72 hours.

c) All restrictions were removed from the machinery spaces (except 'B' boiler and its casings) by D + 6 days.

d) 'B' evaporator was not used for making drinking water until H + 77 hours, being kept distilling to feed tanks during this time, to flush the system.

e) All changing or cleaning of strainers on the seawater systems were carried out wearing rubber gloves until D + 4 days.

3.3. Operation 'FLASHLIGHT'.

3.3.1. This shot was fired at 1014 on 19th June. In this test H.M.S. DIANA was approximately 130 miles from 'ground zero' at the time when fall-out was first detected. The ship was fully closed down by 1245 (with the exception of the canvas screen on 'B' boiler room cross-passage - see 3.1.2.(f) above) and fall-out was reported at 1325.

3.3.2. The fall-out predictions for this test were much more accurate as a result of the lessons learnt from 'HOTSHOT', but unfortunately a large shear in the wind structure gave rise to a zone of very low intensity in the centre of the fall-out ellipse. H.M.S. DIANA passed through this zone between 1325 and 1530, encountering very little fall-out in the process. Following this, a number of attempts were made, as before, to find more, but although a few patches of lightly contaminated water were found, the ship was unable to overtake the cloud. As in 'HOTSHOT', speed varied from 2 to 15 knots, according to whether the object was to change position or to achieve the correct relative wind for prewetting.

3.3.3. The search for more fall-out was abandoned at 2130, and monitoring started at once, as before. Ventilation to all machinery spaces was restored by 2330, and the Port engine was reconnected by midnight. On this occasion 'B' boiler was not shut down, owing to the development of a fuel pump defect in 'A' boiler room. For this and other reasons, it proved impracticable to shut down 'B' Boiler until arrival at Singapore on June 30th, to the considerable detriment of the trials thereon.

3.3.4. As for 'HOTSHOT', details of subsequent monitoring, decontamination etc. are given elsewhere in this report. In this test, however, it was found that as all airborne fall-out had occurred during the first two hours, during which time machinery spaces were fully closed down, the only contamination of spaces other than 'B' boiler blower rooms was a little carried in on watchkeepers' boots. This was relatively easily dealt with, particularly as the use of overshoes to prevent the spread of contamination had by now been introduced.

3.3.5. In general, other restrictions followed the pattern of 'HOTSHOT', but there were some significant differences, viz:

a) Examination of the blades of 'B' boiler blowers showed significant contamination by alpha emitters. Long-term restrictions were therefore imposed on work on the blower interiors until these should have been scrubbed.

/ b) ...

b) Significant alpha contamination was also found in the brickwork of 'B' boiler. Similar long-term restrictions (use of protective clothing and respirators) were therefore imposed on work involving disturbance of brickwork, until such time as either more comprehensive tests than were then possible on board should show the hazard to be less than then apparent, or the boiler had been completely rebricked.

c) As this was the last test of the series, matters such as cleaning the syrens became of interest. It was decided to let the mast and funnels weather, rather than try to decontaminate, and it was found necessary to use masks, gloves and overshoes for cleaning the syren bellmouths until D + 13 days.

MONITORING

4.1 General

4.1.1 The arrangements made for monitoring fall naturally into two parts; those for monitoring during fall-out, and those for monitoring after the search for fall-out had ceased.

4.1.2 The arrangements during fall-out were intended primarily to ensure safety of personnel in the event of unexpectedly heavy fall-out. They were designed to give warning to the command of any unduly high dose-rates, or of any apparently heavy build-up of deposits in the machinery. Secondary objectives were to investigate deck shielding factors, deposit distribution and rate of build-up, and transit doses, and to provide a check on the monitoring surveys after the event.

4.1.3 The monitoring carried out after the event was primarily concerned with guiding decontamination, and with providing as detailed a picture as possible of the position, magnitude and extent of any deposits, whether in the machinery spaces or the machinery. It was hoped also to gain some information concerning shielding factors of decks and machinery.

4.2 Monitoring during fall-out

4.2.1 Monitoring by dose-rate meter was carried out at half-hour intervals throughout the trials, except for occasional periods when it was certain that no fall-out was occurring. This monitoring was, for obvious reasons, not so detailed as that carried out after fall-out had ceased, but it was hoped that it would give some indication of the build-up of contamination, particularly so that if the fall-out encountered should be unexpectedly heavy, steps could be taken in good time to steam the ship out.

4.2.2 It had been agreed previously with the Health Physics Adviser that such steps would be desirable if the dose-rate at any watch-keeping position rose above 100 mR/Hr unless fall-out was clearly about to cease. The basis for this decision was as follows:-

a) The allowable gamma dose for any man was 3R.

b) The transit dose would be most unlikely to exceed 0.5R.

c) It was assumed that the dose rate at any position might be doubled between being reported and the cessation of fall-out.

d) It was assumed that, on a basis of 8 hrs. watchkeeping in 24, any man might receive $\frac{1}{3}$ of the "infinity dose" from his watchkeeping position from H + 8 hours onwards.

4.2.3 The instruments used are shown in Appendix A. The system adopted was that numbered labels were placed in selected positions in "A" Engine Room and "B" Boiler Room, and at half hour intervals during the period of fall-out meter readings at each of these positions were recorded by the watchkeepers. After each series of readings had been taken, the highest recorded dose rate in each space was reported to A.B.C.D. H/Q. by the machinery broadcast, an extension to which had been arranged outside "A" Boiler Room access.

4.2.4 Owing to the difficulty of movement in the ventilated suits, and also to the number of extra duties such as habitability and transit dose records, air sampling, etc. falling on the skeleton watches in addition to their primary one of machinery watchkeeping, the number

/ of

of positions at which dose-rates were recorded was kept to the minimum compatible with obtaining adequate coverage for safety and some idea of shielding factors when compared with other records. The actual positions selected, and results obtained, are shown in Appendix E.

4.2.5 To prevent contamination of the instruments during the periods when machinery space ventilation was open, they were initially supplied for 'HOTSHOT' in stores-issue polythene bags, and without their carrying cases. It was soon found, however, that it was impossible to read them except in the most brilliant lighting, and instructions were therefore given to remove the bags. As it happened, contamination of the meters was insufficient the readings, and was easily removed by wiping with solvent afterwards. It is noteworthy that visibility through either the ventilated suit or a service respirator was excellent, there being no misting whatsoever and only a few 'dribbles' of liquid across the eyepieces or visors. Virtually all the restriction to visibility was that of the polythene bag.

4.2.6 As an additional source of information, to provide data about transit doses, a small number of quartz-fibre dosimeters were suspended in positions normally occupied by watchkeepers. (It had been intended to use a large number of these, but the stock was insufficient for this.) These were also read every half hour, in case any should be unduly affected by heat or humidity. Their positions are shown in Appendix E. In the event, no doses were recorded on any of these, apart from those attributable to the conditions of high temperature and humidity. Two noteworthy points were, however, discovered during rehearsals, the first that machinery space conditions can induce a false reading, and the second that the angle of viewing has an apparent effect on the dose recorded. Details are given in Section 4.6 below.

4.2.7 In the event, the readings recorded during the event were so low as to yield no useful information, apart from some confirmation of the results of the first post-trial surveys (Sections 4.4 and 4.5 below, q.v.). On the other hand, useful experience was gained in operating the equipment under difficult conditions. The question of the transparency of the protective bags has already been referred to (4.2.5 above). Other points were the absence of a meter to bridge the gap between the Contamination Meter No. 1 and the Survey Meter No. 2, and a number of minor points concerning the Contamination Meter No. 1. All these are reported fully in Section 4.4 below.

4.3 Monitoring after fall-out - Outline

4.3.1 As soon as the ship was clear of fall-out and/or the search for more was abandoned, upper deck monitoring parties were sent out, followed by decontamination parties. When the latter had satisfactorily hosed down the ventilation flaps of machinery spaces, the remaining ventilation was restored, and a set of air samples taken in each machinery space for health control clearance. When these had been examined and passed as satisfactory, detailed monitoring of the machinery spaces was started.

4.3.2 The initial survey in all cases was carried out with a Contamination Meter No. 1, the readings reported during fall-out having indicated that no higher-reading instrument would be needed. In order to avoid errors due to using a contaminated instrument, a clean meter was taken for the purpose. Owing to the small amount of fall-out encountered, however, little useful information was obtained from this survey in either test in these two spaces.

/ After

After this first and general survey, a more detailed examination was made, also with a Contamination Meter, in search of any major 'pockets' of contamination, and to determine if possible which surfaces were the most contaminated. As before, the results were unfortunately of little value.

Both these ratemeter surveys were confined to 'A' Engine Room and 'B' Boiler Room as the time required was approximately 2 hours, and it was certain that readings in the other two compartments would be less, and could therefore yield no information unless sizeable readings were obtained.

4.3.3 After the initial ratemeter surveys of the two compartments which had been in use had thus shown that there was nothing to be gained by extending the survey to the other two compartments, representative surfaces in all four machinery spaces were tested for 'loose' contamination by means of 'smear' tests. These tests are carried out by rubbing a piece of filter paper over the surface to be tested, and measuring the activity collected on the paper. (For detail, see Appendix B.).

4.4 <u>MONITORING AFTER 'HOTSHOT'.</u>

4.4.1 Following 'HOTSHOT', readings on the first survey were appreciable, but not sufficiently high to enable any detailed analysis to be made. Results in both 'A' Engine Room and 'B' Boiler Room were similar. In the body of each compartment, dose rates were of the order of 0.2 to 0.4 mR/Hr. in positions not less than 3 feet from material surfaces. The higher readings were found in positions either directly exposed to the ventilation airstream, at upper grating level under an exposed part of the "iron deck" (which, in the area above 'A' Engine Room, was not very effectively pre-wetted), or adjacent to 'B' boiler blower rooms.

The second survey, carried out with the meter probe approximately one foot from the machinery etc. surfaces, served merely to confirm the results of the first. Readings of 4 mR/Hr were obtained generally in positions near the ventilation terminals, and of about 1 mR/Hr in most other areas. Although this was a strong indication that it was in fact the surfaces which were contaminated, and it was not a question of transmission from the upper deck, it was not possible to distinguish individual surfaces, corners or materials as being more heavily contaminated than others. As was to be expected, the readings close to the blower room bulkheads did not show the large relative increase shown by those in the "ventilated" areas, but were of the order of 1.5 mR/Hr.

The mean time for both these surveys was approximately H + 12 hrs.

4.4.2 The tests for loose contamination after 'HOTSHOT' were more informative. Details of the results are shewn in Appendix B, and a full discussion of the results in the generally contaminated compartments in Section 7, (q.v.). It is sufficient at this point to report the general state revealed:-

'A' Boiler Room: Contamination (above "tolerance") on deck plates and ladder treads only. Clearly brought in on boots and shoes.

'A' Blower Rooms: Clean.

'A' Engine Room: General contamination far above tolerance, but worst in 'ventilated' areas, as indicated by ratemeter.

/ 'B'

'B' Boiler Room: As 'A' Engine Room.

'B' Blower Rooms: General contamination, far above tolerance.

'B' Engine Room: Contamination above tolerance on deck plates and ladder treads only. Clearly brought in on boots and shoes.

4.4.3 As a result of these surveys, the use of full protective clothing and respirators for normal watchkeeping was discontinued, and watchkeepers were allowed to use their own overalls, with the addition, in all compartments, of boots, antiflash gloves, and surgical gauze masks. The three latter items of equipment were put on and taken off in the accesses, and were not allowed to leave the compartments (except to join the rapidly growing dump of contaminated gear). The use of masks was not, perhaps strictly necessary from the point of view of air contamination, particularly in 'A' Boiler Room and 'B' Engine Room, but was desirable to prevent transfer of contamination from the hands by drinking, eating or smoking. Details of subsequent decontamination and relaxation of these precautions are given in Section 5.3, but it is necessary to note here that, particularly owing to loose contamination on the upper deck, these precautions were insufficient to prevent the spread of contamination on the soles of boots, and had to be modified for 'FLASHLIGHT'. This was not truly attributable to the system, but mainly to the lack of previous training, a shortage of boots and the lack of access sentries owing to shortage of manpower.

4.5 MONITORING AFTER 'FLASHLIGHT'

4.5.1 Following 'FLASHLIGHT', dose rate readings were significantly lower. In the lower levels of 'A' Engine Room, the rate generally was about 0.15 $mR/_{Hr}$. At the upper levels, rates measured were of the order of 0.2 $mR/_{Hr}$. on the centreline (under the torpedo tubes) increasing to 0.3 $mR/_{Hr}$ at 6 ft. from the ship's side. On the starting platform, at 3 ft. above grating level, the rate was 0.4 $mR/_{Hr}$, probably because the deck above this point was nearly dry throughout the operation. In 'B' Boiler Room a general level of 0.2 to 0.3 $mR/_{Hr}$ was found, with no definable 'hot-spots', although the readings showed a slight tendency to increase as the boiler or blower rooms were approached (as might be expected). There was no noticeable increase in the readings at the upper levels of the compartment, also as might be expected, in view of the funnel superstructure, except that a patch of inefficiently prewetted deck close to the boiler room access which gave a reading of 10 $mR/_{Hr}$ at 4 feet caused a reading of 10 $mR/_{Hr}$ at 3 feet below the access hatch.

The second survey gave no different results from the first, the increases of dose rate observed after 'HOTSHOT' when surfaces were approached with the probe being entirely absent. This was prima facie evidence that, as was already suspected, all fall-out had occurred during the closed-down period.

The mean time for both these surveys was approximately H + 14 hours.

4.5.2 As before, the survey by smear test was more informative. 'A' Boiler Room and Blower Rooms and 'B' Engine Room were found clean, and normal watchkeeping in these spaces was resumed at once. 'A' Engine Room was found to have slight contamination on deckplates and ladder treads only (this was later given more confirmation by the results of tests on the sample plates therein - see Appendix D -). This was probably brought in on boots during the closed down period, when the use of overshoes on the upper deck was impracticable. 'B'

/ Boiler

Boiler Room was likewise contaminated on deckplates and ladder treads only, but more heavily than 'A' Engine Room, as would be expected from the relative distances of the accesses from the citadel. 'B' Blower Rooms were assumed to be generally contaminated, as indicated by a rapid ratemeter survey, which indicated a general level of 4 mR/Hr at 1 ft. from any surface, without any well defined hot spots, and smear tests were only used here to check decontamination. In both 'A' Engine Room and 'B' Boiler Room the telephone mouthpieces were found contaminated, presumably from use by men wearing contaminated respirators.

4.5.3 Precautions taken after 'FLASHLIGHT' were similar though on a much reduced scale to those after 'HOTSHOT'. The experience of transfer of contamination in that event had been employed in the provision of a very large number of pairs of cotton overshoes, which were to be worn by all personnel outside the citadels after the event. This was not only easier to control and enforce than the changing of boots but also relieved the supply problem, as vast quantities were needed. In view of the introduction of this system, which could be expected to minimise further contamination of spaces, the very low level of contamination, and the relative unlikelihood of ingestion from decks, 'A' Engine Room was pronounced 'clean' at H + 15 hours without further decontamination other than cleaning the telephones.

In 'B' Boiler room, not only was the deck contamination heavier, but there was for consideration the need for men to enter the contaminated blower rooms. Accordingly, the precautions ordered were the use of masks, gloves and overshoes. Care was taken that overshoes worn on the upper deck or in the blower rooms were not used in the boiler room. This involved a somewhat complicated organisation, and the establishment of three 'dumps' of clean and dirty segregated overshoes, one at the Boiler Room entrance, and one at each Blower Room door. These were in addition to the piles at the citadel accesses, which latter were guarded by Sentries.

Details of subsequent decontamination are given in Section 5.4. It is sufficient here to report that the procedures worked well, although the consumption of stores was enormous.

4.6 MONITORING - CONCLUSIONS

4.6.1 Most of the general conclusions from this section fall more appropriately under the heading of contamination by ventilation, and are therefore discussed and listed in Section 7 of this report. There are, however, a few which do not conveniently fit this heading, and are accordingly listed here. There are also a number of conclusions, of varying degrees of importance, concerning monitoring instruments, which require to be shewn.

4.6.2 The most important point arising is that there is no equipment in general service capable of detecting the presence of or assessing the risk from loose contamination. If it is accepted that such material can constitute a hazard, then this situation must be regarded as serious. It is suggested that suitable equipment might take either of two forms:-

a) At least two fixed monitoring stations in the ship, with castles and counters for evaluating smears, and a very large supply of filter papers for taking tests. (Approximately 250 smears were taken in the machinery spaces alone in H.M.S. DIANA after each operation).

b) A portable ratemeter, with β-sensitive probe, capable of "tuning-out" a very high gamma background. This would not

/ entirely

entirely satisfy the need, as without some form of smear to test it would not distinguish between fixed and loose activity, but might serve a dual purpose (see 4.6.3 below). The practicability of this suggestion depends to a large extent on the degree of loose activity considered to be a hazard.

4.6.3 The Contamination Meter No. 1 cannot distinguish between local contamination and background from a distance, and is always liable to be swamped by the latter. A possible solution is to equip it with a β -sensitive probe, but means must also be provided for determining, and for suppressing the deflection due to a high gamma background.

4.6.4 In terms of personnel contamination, the Contamination Meter No. 1 appears to be much too insensitive, unless the tolerances to be applied in Service are several hundred times those applied in this operation.

4.6.5 There appears to be a need for a portable ratemeter to bridge the range of dose-rate between 10 mR/Hr (Contamination Meter No. 1, Full scale) and 300 mR/Hr (Survey Meter No. 2, lowest reliable reading). The Survey Meter No. 3 (see Appendix A), obtained from the A.W.R.E. party in H.M.S. NARVIK, appears basically ideal for this purpose. It is light, easy to use and to maintain and appears to stand up well to the very severe conditions in closed-down machinery spaces.

4.6.6 The Polythene bags now supplied to protect portable ratemeters from contamination are insufficiently transparent for use in any but ideal conditions. (In practice, these bags cannot in any case be used effectively without a supply of tape such as Sellotape - which is not a service store - to seal the ends).

4.6.7 If it is accepted that machinery spaces will be closed down during fall-out, it is most desirable that wherever their accesses are outside the citadels, supplies of gloves and overshoes be provided inside the accesses for use by anyone who may have to enter the space during fall-out. These gloves and overshoes to be suitable for use with whatever protective clothing is being worn.

4.6.8 Further to the above, it must be recognised as a matter of routine that on opening up a machinery space after fall-out, the telephones should be cleaned at once. (Unless the space has been unvisited during the closed-down period.)

4.6.9 The following points were noted concerning the Contamination Meter No. 1:-

a) It is doubtful whether the meter can withstand the severe conditions in machinery spaces. That from 'A' Engine Room, although it appeared to give satisfactory readings, required a complete overhaul after each trial.

b) The securing arrangements for the battery box lid are only too likely to work loose and slip.

c) The Carrying handle seriously obstructs the view of the dial.

Points (b) and (c) are only of importance when the meter is used, out of its carrying case, for survey purposes, and are at present, therefore, very minor. If, however, a variant of this meter were to be developed for general use (4.6.2 and 3 above), they would be of considerable import.

/ 4.6.10

4.6.10 The following points were noted concerning the behaviour of the Quartz-Fibre Dosimeters used:-

(a) If charged in normal living-compartment conditions, and then taken into conditions of relatively high temperature and humidity, such as a normal machinery space, some, though not all, dosimeters rapidly recorded a reading of up to 5% full scale deflection before reverting to their normal leakage rate. This extra deflection did not decrease on the dosimeter being brought back to cooler conditions.

(b) If when held up to the eye the dosimeter is rotated about its longitudinal axis, a reading of between 5 and 10% full scale deflection can almost always be obtained in some positions.

Neither of these points are of major importance, but either could be misleading, particularly in the higher-range instruments!

5. DECONTAMINATION.

5.1. General.

5.1.1. This section deals only with decontamination of machinery spaces and the externals of machinery. The safety precautions applied to saltwater systems, evaporators, 'B' boiler, etc. will be found in the appropriate 'Trials' Section of the report.

5.1.2. The principle of such decontamination as was carried out was solely to render the spaces sufficiently "clean" to enable normal watchkeeping tasks to be carried out without protective clothing; in other words, to reduce the level of 'loose' contamination in much used positions to below the established tolerance (see Appendix H), without regard to 'fixed' contamination. No attempt was made to go further than this, awkward corners, lagging, and indeed the majority of the spaces, being left to allow the activity of the contaminant to decay naturally.

5.1.3. This was only practicable as a result of two factors: the exceedingly low level of contamination, which made it unnecessary to consider the external radiation hazard from 'fixed' contamination, and kept the time for natural decay within reasonable limits, and the fact that no major maintenance was either necessary or operationally possible for a considerable time in the spaces which became generally contaminated.

5.1.4. Following 'HOTSHOT', decontamination was handicapped by an acute shortage of fresh water, combined with the fact that the sea-water was reported to be contaminated, and strict orders against its use for any purpose including distilling were in effect for some time after the event. Use of evaporators was further restricted by contamination of one shell (see Section 8.4.). For these reasons the principal means of decontamination was washing with rags soaked in solvent. It is noteworthy that no solvent exists in Service stocks which can be used for this purpose without infringing regulations, and it is for consideration that the rules should be amended to suit this somewhat special case. (The solvent used in H.M.S. DIANA was Carbon Tetrachloride. This was reasonably effective, where the alternative, no decontamination, would have exhausted supplies of protective gear long before decay had reduced the activity to an acceptable level.)

5.1.5. Following 'FLASHLIGHT', the shortage of water was not so acute, though, as in any ship of this class, there was very little to spare, especially as evaporation was again restricted. Very strict rationing was enforced.

5.2. State before Decontamination.

5.2.1. As reported in Section 7, the general state of machinery spaces after fall-out ceased was as follows:-

a) After 'HOTSHOT':

'A' Boiler Room:	Slight (over tolerance) contamination of deck plates.
'A' Blower Rooms:	Clean.
'A' Engine Room:	General contamination, well over tolerance.
'B' Boiler Room:	Ditto.
'B' Blower Rooms:	Ditto.
'B' Engine Room:	Slight (over tolerance) contamination of deck plates.

/b)..

b) After 'FLASHLIGHT':

'A' Boiler Room:	Clean.
'A' Blower Rooms:	Clean.
'A' Engine Room:	Slight contamination of deck plates.
'B' Boiler Room:	Slight, (but heavier than 'A' Engine Room) contamination of deck-plates.
'B' Blower Rooms:	Generally contaminated.
'B' Engine Room:	Clean.

5.2.2. It is unnecessary in this report to give the detailed timetable of decontamination after each operation, except insofar as the time when restrictions were removed, related to the contamination received, is of interest in gauging the importance of avoiding contamination altogether. If required, full details are given in Section IV.F of "H.M.S. DIANA's Report on Operation MOSAIC".

5.3. Decontamination after 'HOTSHOT'.

5.3.1. In the case of the two compartments ('A' Boiler Room and 'B' Engine Room) where contamination was limited to deck plates, a thorough wash-down with solvent was given to all deckplates and ladder treads on the day following the explosion (D + 1). As, however, overshoes were not then available for use on the upper deck, and as their absence had already resulted in contamination of the decks immediately inside the citadel accesses (and immediately outside the machinery space accesses), this washing was completely ineffective, tests afterwards showing as much, and often more, loose activity after washing than had been found before, in spite of the passage of a considerable time for decay. In view of the fact that as stated above, the upper deck and some of the citadel decks were contaminated without any precautions being in force, and since it was considered that the risk of ingestion direct from deckplates was small, it was decided by the Health Physics Authority that precautions in these two machinery spaces (for details, see Section 4, 4.4 and 4.5) could be relaxed. This decision was taken at H + 28 hours.

5.3.2. In the more generally contaminated compartments, the washing down was extended to all surfaces liable to be touched, rubbed against or trodden on in the course of normal watchkeeping. These included handrails, telephones, gauge boards, control gear and handwheels, and some surfaces of machinery, pipework and bulkheads. In the blower rooms of 'B' boiler the more accessible parts of the intake trunking were also washed down. (This latter was with sea-water, the restrictions on the use of which had been relaxed by this time.) In these compartments decontamination was more successful, tests after washing showing that loose contamination had been reduced to an acceptable level, except for deckplates and ladder treads, where the situation was the same as in the other spaces (5.3.1 above). Restrictions on men carrying out normal watchkeeping duties were removed, from 'A' Engine Room at H + 48 hours, and from 'B' Boiler Room and Blower Rooms at H + 72 hours.

5.3.3. For work involving removal of lagging, or access to parts of the spaces not easily accessible, in 'A' Engine Room, 'B' Boiler Room and 'B' Blower Rooms, the use of gauze masks, gloves and special boots, with or without protective overalls as appropriate, was continued until a careful survey, which included raising as much dust as possible from lagging, showed that no appreciable activity remained. These restrictions were then removed, on 22nd May (D+ 6 days). Restrictions on work in 'B' boiler, boiler casings and blower rooms were retained until D + 23 days. (See Section 6.)

5.4. Decontamination after 'FLASHLIGHT'.

5.4.1. As can be seen from the general state of contamination (5.2.1

above,) decontamination after this event was a much simpler process than that after 'HOTSHOT'. The deck contamination in 'A' Engine Room was very slight, and since the provision of overshoes (obtained from U.K. after 'HOTSHOT' had shown the requirement) could be expected to minimise the spread of contamination from the upper deck, all precautions were discontinued in this compartment at H + 15 hours without further decontamination, apart from cleaning the telephones. This left only 'B' Boiler Room and Blower Rooms to be dealt with.

5.4.2. In the case of 'B' Boiler Room, the deck contamination was heavier (to be expected as the access is further from the citadel) and there was also for consideration the need for watchkeepers to visit the blower rooms during their watches. The continued use of gauze masks, gloves and overshoes was therefore ordered, and care was taken that overshoes worn either on the upper deck or in the blower rooms were not worn in the boiler room (and vice versa). On D + 1 the boiler room deckplates and ladder treads were wiped over with solvent, the telephones were cleaned, and the blower rooms and parts of the intakes were wiped and washed as after 'HOTSHOT'. Subsequent tests showed that decontamination had been successful, and the use of protective clothing for normal tasks was discontinued at H + 34 hours.

5.4.3. Unlike the situation after 'HOTSHOT', the only spaces generally contaminated were the blower rooms, so that except in these spaces and in the boiler itself, no further restrictions on maintenance work were necessary. As a result of a survey of the blower rooms and boiler carried out on 3rd July (D + 14 days) restrictions on work in those spaces were removed, with the exception of two, occasioned by the discovery of slight, but significant, contamination of the blower blades and boiler brickwork by alpha particle emitters (long-life activity). These remaining restrictions are:-

a) That protective clothing and respirators must be worn for work on the interior of the blowers until such time as the blower blades and casings have been thoroughly scrubbed.

b) That protective clothing and respirators must be worn for work in 'B' boiler involving disturbance to the brickwork until either further tests have shown the resultant hazard to be negligible or the boiler has been completely rebricked.

5.4.4. After 'FLASHLIGHT' there arose the question of decontaminating the syrens. The whole operation being then over, it was desired to return the ship to a normal state as soon as possible, and the syrens were by this time very dirty indeed. As they were outside the range of the prewetting, they were left to decay as long as possible. Smear tests taken on D + 7 days (after some time at sea and several rainstorms) showed loose contamination well over tolerance, and the bells were therefore cleaned by men wearing protective clothing. It was not until D + 14 days that this precaution could be discontinued.

5.5. <u>Decontamination - Conclusions.</u>

5.5.1. The principal conclusion to be drawn from this section is that if loose contamination is to be considered a potential hazard, it can cause trouble, work and disruption of normal operation beyond all proportion to the general level of contamination. The stowage of stores alone is a sizeable problem, when it is considered that each watchkeeper in 'B' Boiler Room after 'FLASHLIGHT' required, for one watch:

One gauze mask.
One Pair Anti-flash gloves.
Three Pairs overshoes (1 for upper deck, 1 for boiler room, and 1 for blower room use).

/To ....

To this is added a considerable administrative and training problem, and much interruption to normal maintenance owing to the necessity for the use of full protective clothing and respirators, to say nothing of the minor but appreciable discomfort of a full watch in a machinery space in a mask without the possibility of a drink!

5.5.2. Had the contamination been heavier, it would have been necessary for watchkeepers to have worn respirators and full protective clothing, with the resultant problems of decontamination after each watch (the stowage of sufficient clothing to avoid this would be quite impracticable) and of restriction of the duration of watches. Permanent restrictions might have been necessary had the contamination by alpha particle emitters been serious.

5.5.3. It follows that a very considerable effort is justified to endeavour to avoid the possibility of contaminating the machinery spaces. This proposition is given added force if the possibility of heavier contamination, with an appreciable hazard from "fixed" contamination, is considered.

5.5.4. A considerable contribution to the avoidance of contamination could be made in H.M.S. DIANA by removing the turbines, steam pipes, etc. of the boiler blowers from the combustion airflow. The fact that it is necessary to enter the blower rooms, and, owing to the restricted space, rub against a considerable amount of contaminated machinery, to stop or start a blower, or even to see that one is running correctly, is a probable cause of contaminating a man, his clothes and an otherwise clean boiler room long after passage through fall-out. In addition, the contamination of the blower room might well be heavy enough to make a hazard of entrance. (See Section 6.)

5.5.5. Very great help in avoiding the spread of contamination, and hence in obtaining reasonable decontamination, was found from the provision of A.E.A.-pattern cotton overshoes. These are apparently cheap, (necessary as after use they must be disposed of) and are easy to stow in very large quantities. This latter is of major importance, as in the event of heavy or widespread contamination the usage rate will be enormous, particularly during decontamination, when there may well be a number of places in different states, requiring several changes (as in 'B' Boiler Room after 'FLASHLIGHT').

5.5.6. It is clear that, for the cases (rare, it is to be hoped) where some contamination does enter spaces, stocks of solvent are most desirable. Water is not completely satisfactory, especially on surfaces which are even slightly oily or greasy, and may in any case not be available in sufficient quantity, especially if much decontamination of personnel is necessary. (Very little was required in H.M.S. DIANA, in either trial.) If, as seems likely, there is no solvent which is acceptable in normal circumstances, this use must be considered exceptional, and stocks carried for this one eventuality only.

6. TRIALS - BOILER CONTAMINATION

6.1 Outline - Arrangements.

6.1.1 As can be seen from the objectives of the trials under report as whole (Section 1), this particular trial had two purposes, to find the distribution of contaminant deposits, if any, in the boiler gas path, and to find the correlation, if any, between the behaviour of active fall-out and that of chemical tracer, as revealed in the trials already carried out in H.M.S. DECOY, (E-in-C. report 5086R of April 1956).

6.1.2 These two objects were not entirely compatible, as the former involved applying the lessons from the 'DECOY' trial, whereas the latter required the arrangements to be as nearly as possible the same. In the event this was not however of great consequence, as wil be seen from what follows.

6.1.3 The general outline of the trials arranged was that air samplin pumps, by drawing gas through a fine filter, would take continuous samples from immediately inside the air intakes and the base of the funnel. These samples, by comparison with similar samples taken by the Scientific Team on the (unprewetted) forecastle, would enable estimates to be made of the relative concentration of contaminant in the air at the three points, and hence of the amount which in any given circumstances, could be expected to remain in the boiler system (It was originally intended to have an additional sampling point either at entry to or discharge from the blowers, but sufficient pumps could not be obtained for this.) In addition to this 'total air' sampling, small steel plates, portions of firebrick, and small pieces of asbestos cloth were distributed throughout the gas path, as indicators of the amount of deposition on the various surfaces. Samples of soot and brickdust were also obtained after the events. It was originally intended to sample the soot both before and after soot blowing, but this finally proved impracticable in either event (see below).

6.1.4 The steel plates were of stainless material, and the brick samples were cut from a piece of the brick normally used in the boiler. All samples were placed in position some time before each event, so that at the time of contamination the surface would be in the same condition as the surface to be represented. (This caused a number of casualties among the brick samples, of which there were intended to be thirteen for each test, but was in any case unavoidable for samples in the boiler itself.)

6.1.5 Siting of samples in the boiler itself was as nearly as could be arranged the same as the siting used in the chemical trial referred to (the DECOY trial), but a number were sited in parts of the air casings which had not been properly sampled in that trial. In addition, much greater attention was paid to siting samples in the blower rooms and intakes, the 'DECOY' trial and other information having shown that heavy deposition here was to be expected.

6.1.6 Details of the positions of samples are shown in figs. 2-10. All samples were attached to their surfaces so as to lie as nearly as possible flat against them. This was not, of course entirely possible, and when testing samples, both sides were tested and the highest result taken. Steel and lagging samples were secured with seizing wire, and care was necessary both in siting and securing these samples to allow for the fact that their removal would have to be carried out in protective clothing. Very neat or tight securing was to be avoided! The brick samples were secured to the furnace floors by fillets of fireclay. Some doubt was felt as to whether these samples would withstand the conditions of high power steaming immediately before the tests, but in the events casualties were

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reasonably light, and the samples were easily removed afterwards with a hammer, though usually only half the sample was actually recovered.

6.1.7 The filters used in the gas samplers were of paper, and were in fact spare filters for the type 1195A portable dust sampler used in other tests. Originally it had been thought that a paper filter would char in the uptake sampling point, and glass cloth filters were supplied, but these appeared on inspection to be very much too coarse for the expected particle size, and tests during rehearsals showed that the paper would stand the uptake conditions satisfactorily. As a precaution in the events, both paper filters were "backed up" by the glass cloth filters, but this would be unnecessary in any future tests. It would, however, have been desirable to use paper of more accurately known retention characteristics.

6.1.8 The arrangement of 'DIANA'S' intakes can be seen from the figures. In both operations the outboard flaps, opening direct on to the weather deck, were closed, and air was drawn in only from the cross-passage. Thus it may be said that the intakes were as well protected from direct fall-out as is ever likely to be the case in any modern warship.

6.2 Operation 'HOTSHOT'

6.2.1 The samples in the boiler casings and furnaces for this test were placed in position while the ship was at Gibraltar on 4th April. This was earlier than desirable, but was as late as it could be certain that the boiler could be entered before the first event, as the passage scheduled allowed little time to spare, and this type of boiler requires 48 hours for cooling before the casings can be entered for any length of time.

6.2.2 Seventy-one plates and thirteen brick samples were placed in the boiler itself. A further twenty-three plates were sited in the blower rooms and intakes about a week before the explosion. It was recognised at the time that more would have been desirable, but there were only 200 plates available for both HOTSHOT and FLASHLIGHT, and some of these were required for the diesel alternator (see Section 9.2). An effort was made to cover the starboard room thoroughly and only have such samples in the Port room as would serve for correlation, but the later decision, arising from the alteration in ventilation plan, to screen the Starboard end of the cross-passage, made this a failure. Fortunately the air sampler was in the Port intake.

6.2.3 All arrangements worked satisfactorily during the operation itself, and the boiler was shut down, without blowing soot, almost immediately afterwards. Samples were recovered as soon as possible, and soot samples were taken. The air samples from the forecastle were very erratic. Sample recovery was carried out wearing the A.W.R.E. protective suits and respirators. Unfortunately the boiler had been rather heavily contaminated with salt feed water during the event, owing to the acute water shortage, and was further suspected of leaking (later disproved). It was therefore not practicable to raise steam, blow soot and shut down again as had been originally intended to sample the effects of sootblowing. From the boiler records, it is seen that the boiler was steaming at about 25% full power on all blowers while fall-out was occurring.

6.2.4 In the first instance after 'HOTSHOT' only a representative selection of plates were recovered from the casings. All samples were taken from the blower rooms, intakes and furnaces, and it was

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felt that as the fall-out had been so light, the cause being known and correctable, and as this course would enable more samples to be used for 'FLASHLIGHT', the rather onerous task of removing all the samples from the casings was not justified unless preliminary examination showed either an unexpected distribution of contamination, or a level too high to have decayed to background by the time 'FLASHLIGHT' was expected. In the event, neither of these were found.

6.2.5 Decontamination of the boiler was not attempted. No work was required in the casings, but access for inspections etc. was confined to men wearing protective clothing until D + 23 days (8th June). The same precautions were required for work in the furnace, except that for water washing, which was carried out on D + 17 (2nd June), the requirement for respirators was relaxed, as it was considered that the water would keep down any dust.

6.3 Operation 'FLASHLIGHT'

6.3.1 In preparation for 'FLASHLIGHT' all the plates which had been removed from the casings after 'HOTSHOT' were replaced on 28th May. (This work required protective clothing again - see 6.2.5 above). For ease of indexing, replacements were used bearing the same numbers plus one hundred. Brick samples were placed in the furnaces on 3rd June.

6.3.2 The samples in the blower rooms and intakes were positioned on 1st June. As there were now more plates available, the coverage was made much more thorough, a total of 48 being used, bringing the number of plates in the system to 119. Twenty four plates were allocated to the ventilation trials in 'A' Engine Room (see Section 7 In addition, there were by now available some small pieces of lagging cloth, of which four were strapped to selected pipes in the Port blower room. (It was intended to screen the starboard end of the intake cross-passage, as in 'HOTSHOT').

6.3.3. Arrangements worked more or less satisfactorily in the event. A last minute alteration to the E.T.A. of the fall-out made it impossible to rig the cross-passage screen, but this can hardly be considered a disadvantage to the trials. The intake sampler pump apparently developed a diaphragm fault during fall-out, but fortunately the uptake sampler was satisfactory, and the only loss, a direct comparison of the relative contamination received in the two events, can be partly made good by comparison of the overall contamination of samples. As before the contamination of the forecastle samplers was exceedingly erratic and confusing. From the records it is seen that the boiler was steaming at about 20% full power while fall-out was occurring.

6.3.4 In this case, it was not possible to shut down the boiler at once, owing to a fuel pump fault in 'A' Boiler Room. By the time this had been remedied other operational matters made it essential to continue steaming on 'B' boiler, except for periods too short to allow entry for sample recovery. The gas sampler filters, and all samples from the blower rooms and intakes, were recovered on D + 2, but it was not until D + 13 (2nd July) that the samples from the casings and furnaces could be recovered, by which time, as a corollary to continuing to steam that boiler, it had been necessary to blow soot several times. Soot samples were nevertheless taken, and also samples of crumbled brick from the water wall, and smear tests of the blower blades and casings (inside).

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6.3.5 Decontamination was, as before, not attempted. As a result of tests of the samples, restrictions on entry to the air casings were removed on D + 14 (3rd July), but tests of the blower blade smears and the water wall brickdust showed significant contamination by alpha particle emitters, and it was necessary to order the continued use of protective clothing and respirators for work either involving disturbance to brickwork or on the interiors of blowers until such time as the blowers had been scrubbed and/or either the boiler should have been rebricked or further tests while such work was in progress should show the restrictions to be unnecessary, as appropriate. (Owing to external circumstances, neither of the two latter eventualities has occurred by the time of writing).

6.4 <u>Results</u>

6.4.1 The results of tests on the samples from the boiler are shewn in Appendix C, and the details of their analysis in Appendix G. Some details of the characteristics of the fall-out, as found outside the ship's prewetting system, and such figures as are available to assess the proportion which entered the intakes, are shewn in Appendix D. Records of boiler operation during fall-out are given in Appendix F. The purpose of this present section is to attempt to correlate all details from these results, and to form conclusions therefrom. The principal reference in what follows is to Appendix G, Table G.3.

6.4.2 On the question of the proportion of the fall-out that entered the protected intakes through the pre-wetting it is not possible to be specific. A large quantity of the active material falling on the forecastle filters is believed to have been lost by falling off, particularly in 'HOTSHOT' when both filters were nearly vertical, the air flow being at an angle of about 30° downwards through them. A better comparison can be gained by using the total from the cascade impactor and from 'FLASHLIGHT' for which some of the collectors were at different angles, varying from horizontal to vertical. Unfortunately the boiler intake sampler failed during this operation, but it seems reasonable to assume, from comparison of the plate sample analyses, that boiler contamination in this operation was of the order of 85% of that in 'HOTSHOT'. This is in fact borne out by the impactor counts. The comparison is discussed in some detail in Appendix D, and it is concluded that a reasonable <u>minimum</u> figure for the proportion of contamination reaching the intakes is 75% of that outside the prewetting, and that a more realistic estimate is very closely approaching 100%. It is also concluded that the possibility of intake contamination far exceeding that in the open air must be considered, if contaminated seawater is used for prewetting. The boiler intake sampler was carefully sited to minimize the impaction effect, and must therefore be considered to underestimate the contaminant entering.

6.4.3 It appears quite clear that of whatever contamination entered, virtually none, or at most a trace only, emerged from the funnel.

6.4.4 The results of the various plate sample analyses are remarkably similar, bearing in mind the very extensive approximation employed and the accuracy of both the counts and the method. It is noteworthy that all the major deposit figures appear in those places where the counts themselves are most reliable, and that virtually all the small counts are associated with areas such that the total estimated deposit can only in any case be described as 'trace'.

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6.4.5 The principal deposits appear to have been, as expected, in the intakes, furnace brickwork and soot on tube nests, and in the case of 'FLASHLIGHT' in the blower rooms. The boiler casings received only a trace, as did the uptakes and funnel, though here, clearly due to the soot, the contamination is a little heavier.

6.4.6 The estimates for intake deposits are reasonably similar, though an extraordinary feature is the consistent disproportion between sides. This is the more peculiar in that it is not repeated in the blower rooms in either test. It cannot be accounted for (except in 'HOTSHOT') by the screen at the cross-passage end, as this was not present for 'FLASHLIGHT', nor by any preponderance of wind from the Port side, as the ship was constantly 'weaving' either side of head-to-wind. It is suggested as a bare possibility that the seaboat in davits on the starboard side (not present on the Port side, where there is a Carley Float stowage in lieu) served to break up the airstream, causing the larger particles, which would obviously be the first to deposit, to do so outside the intake.

6.4.7 From the fact that the blower room deposits appear more or less equal on each side in both tests, it appears reasonable to assume that the shielding on the Starboard side, whether from the canvas screen in 'HOTSHOT' or from any other cause, removed only the largest of the particles, such as would not have passed the intakes in any case. Further, it is reasonable to suppose, from the consistency of results, that the proportion of total deposits occurring in the intakes is of the order of 35-45%.

6.4.8 There is a noteworthy difference between the deposits in the blower rooms after 'HOTSHOT' and those after 'FLASHLIGHT'. This is probably accounted for by the difference in particle size (see Appendix D, Table D.4) which in the main was somewhat smaller in 'FLASHLIGHT' than in 'HOTSHOT', and could therefore be expected to penetrate further before depositing. Contamination of the blowers themselves appears from the smear test results to have been of the same order as the contamination of the blower rooms generally.

6.4.9 The results from 'FLASHLIGHT' are not strictly comparable with those from 'HOTSHOT' without allowance for sootblowing, which in view of the soot activity must obviously have considerable effect. The proper allowance does not clearly emerge from these trials, but when an approximation is made (see below), the similarity between the totals of blower room and intake deposits is remarkable. It appears from this that about 35-45% is a reasonable figure for the proportion of total deposits to be found in the blower rooms and intakes.

6.4.10 The boiler casings do not appear to have retained more than a trace of the contamination, mainly at positions near bends in the airstream or near the blower outlets, and more or less proportionate to the air consumption of the furnaces, wherever this is likely to cause division of the airstream.

6.4.11 The furnace brickwork appears as expected to have retained a fairly large quantity of the contaminant. The apparent difference between the retention in the two events is almost certainly a function of the chemical characteristics of the fall-out itself or its carrier. As to actual proportion likely to be retained, it is

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impossible to be specific, owing to the self absorption of the bricks, but it appears reasonable to suppose that up to 25% might be retained in similar circumstances.

6.4.12 Also as expected, the tube nests appear to have retained a very large proportion of the contaminant, chiefly it is justifiable to assume, in the form of soot. It appears reasonable to assume a likely retention in similar circumstances of between 30 and 50%, depending on the time since the boiler was cleaned. (It had been cleaned externally very shortly before 'FLASHLIGHT' (see 6.2.5 above)).

6.4.13 The effect of sootblowing could not be investigated directly, owing to the chain of circumstances described in Sections 6.2 and 6.3 above. An attempt to assess it has however been made (see Appendix G), which although open to considerable criticism is at least partly justified by a reasonable similarity between the decay rates in the early stages after the two operations. The main justification is, however, the desirability of obtaining some information, however vague.

6.4.14 From this approximation it appears that the effect of soot-blowing is not as great as could be desired, apparently reducing the contamination of the tube nests by something of the order of 50% only. Even this reduction is, however, well worth while. Arising from this, it is quite clear than when blowing soot after contamination of this sort, the importance of keeping personnel and equipment clear of the effluent from the funnel can hardly be overemphasized! It might well be necessary after any serious contamination, to remonitor a large proportion of the upper deck and superstructure after each sootblowing for some time.

6.4.15 The funnel and uptake appear to have retained only small quantities of active material, though somewhat more than the boiler casings, and considerably more in terms of deposit per unit area. This is contributory evidence that, as seems indicated throughout, the active material leaving the furnace is carried by the soot.

6.4.16 To compare the results of these trials with those carried out in H.M.S. DECOY with chemical tracer (E. in C. Report 5086R of April 1956) is not easy, as in the 'DECOY' trials little attention was paid to the intake trunks and blower rooms and gas sampling was a failure. On the other hand, the general conclusions are the same. The conclusions from this trial regarding overall retention and retention in intakes and blower rooms have clearly far more general validity than those from the DECOY trial. The conclusions regarding percentage retention in other positions are however reasonably similar, if allowance is made for the first two points. It seems probable that if, in the DECOY trial, the contaminant mist had been put up <u>outside</u> the intakes, and better air and gas sampling methods employed, the overall results would have been very similar to those obtained from 'HOTSHOT'.

To this there is one exception. The assessed efficiency of sootblowing in the DECOY trial was clearly much too high. More attention to this point is essential in future trials, and the 'DECOY' results must be treated as exceptional until a better method of assessment is found.

6.4.17 It is not possible in this report to assess fully the implications of the results in terms of wartime hazard. It appears likely however that the order of hazard in the event of heavy, but not extreme, contamination might be as follows:-

(a) The boiler as a whole might be a severe, though not lethal, hazard to watchkeepers in the boiler room for some time after the event. Hazard to personnel in adjacent spaces would probably not be great, unless adjacent to the intake trunks.

(b) Access to the blower rooms or intakes (e.g. to attend to or stop or start blowers) might well be a lethal gamma hazard for some time. It is therefore of great importance that controls etc. should not be sited here.

(c) Access to any part of the boiler, its casings, intakes, uptakes and funnel would present a serious inhalation and ingestion hazard for a long time after the external radiation hazard had decayed to negligible proportions. It would probably not be possible ever to relax precautions if the fall-out contained a significant quantity of long-life elements.

(d) Leakage from the air casings could be a cause of serious contamination of the boiler room, in view of the amount of contaminant apparently passing the blowers.

6.4.18 Concerning the conduct of future trials, it is considered that the conclusions on this subject reached from the 'DECOY' trials stand virtually unchanged. More thorough air sampling is necessary, including a sampler either at the entry to or discharge from the blowers, and it would be highly desirable to have at each sampling point a cascade impactor or other means of measuring particle size distribution, operating over a wider range of particle sizes than the impactors used in this operation. Plate samples in the boiler casings can now, if is felt, be reduced to a minimum, and more attention paid to the intakes and, if possible, the tube surfaces.

6.5 Boiler Trial - Conclusions

This sub-section sets out briefly the conclusions derived in the previous sub-sections.

6.5.1 It is clear that airborne fall-out can and will enter boiler air intakes, in spite of prewetting, even if the intakes themselves are in relatively protected positions. The proportion of contaminant entering must be expected to be at least 75% of that outside the prewetting, and is more likely to be very nearly 100%. If heavily contaminated seawater is used for prewetting, it may in effect very considerably exceed this figure, even to the extent of 280%, found apparently in this trial.

6.5.2 It is clear that of whatever contamination enters the boiler system, virtually none emerges from the funnel. That which may do so appears to be carried on soot particles.

6.5.3 The major sites for deposition of the contamination are the intake trunks and blower rooms, the brickwork and the soot (therefore the tube nests). Some impression of the deposits to be expected would be:-

Intakes and blower rooms:	35-45% of that entering.
Furnace Brickwork:	Up to 25% of that entering.
Tube nests:	30-50% of that entering.

Tube nest deposits will to some extent depend on time since the boiler was cleaned.

/ 6.5.4

6.5.4 The boiler casings, uptakes and funnel may be expected to retain a trace (up to, say, 5% total) of the contaminant. The funnel and uptakes, on account of the soot, will contain more than the air casings.

6.5.5 Sootblowing will remove some of the contamination, but should not be expected to remove more than 50% of the tube nest contaminant, even if repeated. Great care would be required in wartime to prevent danger to personnel and recontamination of the ship.

6.5.6 The implications of this in wartime appear at first sight to be that if subjected to heavy, but not extreme, fall-out:-

a) The boiler as a whole would be a considerable, though not lethal, hazard to watchkeepers or to personnel in compartments adjacent to the intakes and blower rooms for some time after the event.

b) Access to blower rooms or intakes might well be a lethal hazard, and it is therefore essential that no controls, or machinery requiring frequent inspection, be sited there.

c) Access to any part of the boiler casings, furnaces, uptakes, etc. would present a serious 'internal' hazard for a very long time particularly if a significant quantity of alpha-particle emitters were present.

d) Air leakage from the casing, if considerable, could cause serious contamination of parts of the boiler room.

6.5.7 There appears to be a most satisfactory degree of correlation between the results of these trials and those of the chemical trials carried out in H.M.S. DECOY. It therefore appears that a waterborne chemical mist can be satisfactorily used for future trials, provided means can be found for better assessment of tube nest deposits, and for creating a uniform mist <u>outside</u> the intakes and prewetting system (if applicable).

6.5.8 In any future trials, more attention must be paid to air sampling, and to particle size tests. Plates in the boiler air casing may be reduced to a minimum, and more attention paid to intakes and tube surfaces.

6.5.9 More experiment is required before the amount of contaminant likely to enter the intakes can be properly estimated. Tests should take into account the possible augmentation of intake contaminant from the prewetting system. It does not appear that these tests can be carried out with simulated fall-out.

7. TRIALS - CONTAMINATION BY VENTILATION.

7.1. Outline - Arrangements.

7.1.1. As originally arranged, there was considerable doubt whether the Health Physics Advisers would consent to the ventilation being opened at all, or if so, under what conditions and for what time. There was therefore no opportunity in advance for setting up a very elaborate trial.

7.1.2. When it became evident in rehearsals that, owing to the limitations imposed by conditions in the air-ventilated suits, ventilation would have to be opened after at most 2½ hours whether or not fall-out had ceased, more detailed arrangements were made.

7.1.3. It was not possible to arrange for total air sampling at the intakes and terminals in the same way as was done for the boiler trial This should be an essential part of any further trials. Instead, a type 1195A portable dust sampler was used. Also unfortunately, there was only one of these available, which necessitated a somewhat complicated and time-consuming organisation for transferring it from one space to the other, particularly as the skeleton watches were so depleted that an extra man had to be brought out from the citadel for this task, and to collect the samples for evaluation. It was in the end arranged that samples from the five positions shown below would be taken at hourly intervals after the ventilation was opened, and sent in to the citadel for testing at once. If at any time the Scientific Team considered that no fall-out was occurring, sampling was to cease for the time, partly in order to conserve manpower and partly to conserve sampler filters, as these latter could not be reloaded and issued in the circumstances.

7.1.3. The five positions selected were:-

a) At the entrance to 'A' Engine Room supply vent on the upper deck.
b) At the supply terminal in 'A' Engine Room on the starting platform.
c) At the entrance to the exhaust duct from 'A' Engine Room, for'd.
d) At the outlet from 'A' Engine Room exhaust vent on the upper deck.
e) At the supply terminal at 'B' Boiler Room control position.

the location of points (a) to (d) inclusive may be seen from Fig.11.

7.1.5. The two upper deck positions (a) and (c) required the arrangement of a temporary power supply point for the sampler. This involve some risk of failure owing to damage by the prewetting, but this risk had to be accepted. No extensive sampling was carried out in 'B' Boiler Room system, as it was impossible to take samples at all close to the (natural) exhaust, which passes up the funnel casing.

7.1.6. The systems in use in 'A' Engine Room are, unfortunately, rather close together in the compartment, with a tendency to "short-circuit", but the other systems were altogether too unprotected to be used in these operations.

7.1.7. To investigate the results of such contamination as might be found, reliance had to be placed on the various after-fall-out monitoring surveys (sections 4.3-5 above), as supplies of sample plates, etc. from the boiler trial were not sufficient to spare any for this additional trial. (Since all the boiler samples were not removed after 'HOTSHOT', this situation was remedied for 'FLASHLIGHT', but unfortunately to no purpose.)

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7.2. Narrative.

7.2.1. The arrangements described above worked reasonably well throughout 'HOTSHOT', with the exception of the upper deck sampling points, which were put out of action by the prewetting at an early stage. This appears to be an inherent drawback of the use of portable samplers, and gives added force to the need for "total" sampling by fixed equipment in future trials.

7.2.2. Air sampling started as planned immediately the ventilation was opened (at 1500), but as no fall-out was reported, and these samples showed no contamination, no further samples were taken for the time being.

7.2.3. The first set of samples to show contamination was taken at 2000. (Although fall-out is now suspected of having started at 1910, it was not then definitely known, and was not reported as worth sampling until 1945.) The results of tests on these samples are shown in Appendix D, Table D.1. The next samples were due to be taken at 2100, but a report reached the Engine Room in error that fall-out had temporarily ceased at 2110, and in view of the time necessary (30 minutes) to obtain a full set of samples, this series was not completed.

7.2.4. The monitoring surveys after fall-out (section 4.4 above) gave indications of fairly general contamination of the two compartments. Unfortunately the contamination was not enough to give any considerable dose rates, but the limited rates found, together with the assessments of loose contamination (see Appendix B) can be made to yield a certain amount of useful information.

7.2.5. For 'FLASHLIGHT', as reported in 7.1.7 above, a number of spare sample plates etc. were available from the boiler trials. These were therefore distributed around 'A' Engine Room in such a way as to represent surfaces of various types in different positions relative to the ventilation. The positions selected are shown in Fig.11. In other respects the arrangements were the same as for 'HOTSHOT', except that efforts were made by using protected plug-boxes to prevent the failure of the upper deck power supply to the sampling points.

7.2.6. All arrangements worked satisfactorily except the upper deck sampling points, which again failed due to prewetting. In this case, however, the first tests after opening the ventilation showed no contamination, (as was in fact expected), and it was definitely known that no fall-out was encountered thereafter. No results could therefore be obtained.

7.2.7. The monitoring surveys after 'FLASHLIGHT' (section 4.5 above) confirmed what was already strongly suspected, that fall-out had ceased before ventilation was restored. Contamination was therefore limited to deckplates and ladder treads, brought in on boots while overshoes could not be used owing to the prewetting, and a little on telephones, probably due to their use by men in contaminated protective clothing. The results of these surveys were later confirmed by tests on the sample plates and lagging, results of which are given in Appendix D, Table D.2.

7.2.8. In both 'HOTSHOT' and 'FLASHLIGHT' a certain amount of prewetting water entered the ventilation of the engine room, but does not appear to have affected results materially. None appeared to enter the Boiler Room.

/7.3. ......

7.3. Results.

7.3.1. As a result of the various circumstances described above, results are mainly confined to a single series of air samples and the monitoring survey carried out after 'HOTSHOT'. Details of these are shewn in Appendices D and B respectively. A certain amount of information can, however, be obtained from the boiler trial, since the intakes to the boiler, the outboard flaps being shut, were virtually identical to those of the boiler room ventilation, and rather better protected than those of the engine room. Further, the air indraught was very much the same in all cases, as far as could be ascertained by rather crude means. If anything the indraught to the boiler was less than that to any ventilation intake.

7.3.2. The first and obvious result of these trials is to show that airborne fall-out of the particle size encountered (see Appendix D) ca and will enter ventilation intakes, even though these are protected by position and construction and by prewetting.

7.3.3. Although it is not possible to deduce the exact proportion of the air contamination outside the prewetting which enters the intakes, it is reasonable to conclude from the results of the boiler trial (section 6), and the similarity of intake arrangements (7.3.1 above) that this proportion is a large one. 75% would be a reasonable minimum estimate, and it is most probable that the actual figure closely approaches 100%, and may well appear higher if the water used for prewetting is contaminated.

7.3.4. That the particle size of the fall-out encountered is not such as to make the results useless is deducible from the fact that samplin arrangements much closer to ground zero in these operations received large proportions of active material in even smaller particles. It is of course, assumed that the smaller the particle, the more easily it will enter intakes. This can be considered proven in a number of different ways.

7.3.5. Again, it is not possible to deduce the exact proportion of the contamination retained between the upper deck intakes and the terminals in the machinery spaces. This must of course depend to som extent on the configuration of the system. By comparison with the boiler trial, however, and consideration of the systems concerned, it seems likely that not more than 60% of that entering the intakes emerged into the machinery spaces. The actual concentration in the spaces is surprisingly similar, considering the difference in systems, which leads to the supposition that most of the retention occurs in the fans, which in this case were similar. (Axial flow, 12,000 ft^3/minute.) The resultant fan contamination might well be a serious hindrance to maintenance in wartime.

7.3.6. From the results of the air sampling in 'A' Engine Room, all th can be deduced is that not more than 50% of the contamination entering the space was 'rejected' to the exhaust ducts. This must, however, b considered an above-average figure, as the ventilation systems used only positively ventilated half the space, and were rather close toget producing a partial "short-circuit". That this is so can be seen fro the results of the monitoring, in that 'B' Boiler Room, for a very similar air contamination, shows loose contamination generally about 20-25% higher than that in 'A' Engine Room, neglecting equipment much handled or trodden on. It is suggested that a fair average for retention in the space would be 70-80%.

7.3.7. Applying the same retention to the exhaust system as to the intake, it is deducible that, very approximately, the air contaminatio

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through the system is of the following order of magnitude:-

At upper deck intake:- 100%.
Retained in fan and trunking:- 40%.
At supply terminal in space:- 60%.
Retained in space:- 45%.
At Exhaust terminal in space:- 15%.
Retained in fan and trunking:- 10%.
At upper deck exhaust:- 5%.

7.3.8. Considering now the results of this contamination, very little can be said concerning dose rate in the spaces, except that the results recorded were of much the same order as those recorded on the pre-wetted upper deck above. (See "H.M.S. DIANA's report on operation MOSAIC", Section II, Appendix B, where it appears that the rates found were fairly evenly about 4 mR/Hr at one foot.) This in itself is some guide to what may be expected from heavier contamination.

7.3.9. Results of the tests for loose contamination show that a great deal of the contamination of the spaces was "loose" by health physics definition, i.e. that it can easily be transferred by handling or rubbing, and may therefore easily reach the mouth, either by direct transfer or by breathing as dust. That this is a very real risk is at once obvious from comparison of the tests from surfaces constantly handled with others. Experience of the precautions and decontamination required to deal with this hazard indicate firstly that full decontamination is virtually impossible, and secondly that the precautions required are so extensive and cause such interference with normal operation and maintenance that such contamination must be avoided if at all possible, even though the external (gamma) radiation hazard from it is completely negligible.

7.3.10. Discounting the tests from much-used surfaces, which serve only to indicate that the risk from this loose contamination is by no means negligible, the test results do not give any convincingly definite evidence of the magnitude of contamination on different surfaces. It is clear that no surfaces were free from contamination, and there is considerable evidence that those surfaces remote from the direct air-stream received only between $\frac{1}{3}$ and $\frac{1}{2}$ the contamination deposited on surfaces in or near the airstream. There appears to be little difference between the contamination of any surfaces apart from these factors.

7.3.11. The apparent conclusion that lagging is not likely to become more contaminated than other surfaces in its immediate vicinity is patently invalid, as a 'smear' test cannot distinguish contamination which is not loose on the surface at the time of test. The ratemeter readings are insufficiently large to provide any evidence on this point, nor is any provided by the lagging samples from 'FLASHLIGHT', or the samples from the boiler blower rooms.

7.4. Ventilation Trial - Conclusions.

In this sub-section are set out briefly the conclusions derived in the earlier sub-sections, or deducible directly therefrom.

7.4.1. That airborne fall-out of the particle size encountered in these trials will enter ventilation intakes, even though these are protected by position and construction, and in spite of their reasonably efficient prewetting. Also that the particle size encountered was not such as to make the test results inapplicable to heavier fall-out, as might be found in wartime.

7.4.2. That of the contamination present outside the ship's prewetting, a large proportion, probably virtually all, will reach the ventilation intakes, whereas very little indeed will emerge from the exhausts.

 /That ....

That entering may be augmented by active material from the prewetting water.

7.4.3. That a fairly large proportion (up to 50%) of that entering the intakes may be retained in the supply system, mostly in the neighbourhood of the fan.

7.4.4. That a very approximate estimate of the contaminant concentration at various points might be:-

At upper deck intake:	100%.	
At supply terminal:	60% - 35%	retained in fan and trunking.
At exhaust hood:	15% - 45%	" " machinery space.
At upper deck exhaust:	5% - 10%	" " fan and trunking.

The inference, that any subsequent work on supply fans might involve considerable hazard, both external and internal, must not be forgotten.

7.4.5. That the resultant contamination of a machinery space will extend throughout the space, all surfaces (other than lagging) being more or less equally contaminated, except that surfaces in the neighbourhood of the ventilation airstream will receive about two or three times more contamination than others. Lagging may be more heavily contaminated because of its porous surface. Deckheads, obviously, will not be so heavily contaminated. It must also be borne in mind that the contamination in the intake trunks may well be dislodged later, causing considerable recontamination of the space and, while being dislodged, airborne hazard in the space.

7.4.6. That a very approximate indication of the gamma dose rate to be expected as a result would be that positions ventilated directly would give the same or slightly less than the rate on the prewetted upper deck, with rather less than half this figure in positions remote from the ventilation. If all the ventilation were running, and if all intakes were as protected as H.M.S. DIANA's, these rates might be doubled.

7.4.7. That much of the deposited contamination is loose, and can easily be transferred either via hand and mouth to the stomach, or as dust to the lungs. This type of contamination must be considered a hazard even in quantities which do not give rise to an appreciable external dose-rate.

7.4.8. That some guidance must be given to the Fleet as a whole as to the risks arising from various degrees of loose contamination, preferably with some target figure below which the hazard may be considered operationally acceptable.

7.4.9. That full decontamination of a machinery space is not practicable and that even partial decontamination involves such quantities of time, labour and stores, and the precautions involved are so complex, that great efforts are justified to avoid contamination at all.

7.4.10. That if any further tests of this nature are carried out, continuous air sampling at four points (the upper deck terminals and the terminals in the space itself) for each space tested, is essential, and the plate sample technique should be used throughout.

7.4.11. As a secondary conclusion, that if any further tests are carried out, preparations should be made on the assumption that protective clothing will be required for work in the spaces for a considerable time afterwards, and that if any appreciable alpha contamination is encountered, full decontamination may be essential (c.f. restrictions to work on boiler brickwork, 3.3.5 above).

8. TRIALS - EVAPORATORS AND FRESH WATER SYSTEMS

8.1 Preliminary

8.1.1 It was originally intended that 'B' evaporator (in 'B' Boiler Room) should be kept distilling to feed tanks throughout the tests, and samples taken at intervals of the feed water and made water for subsequent comparison. In addition, scale samples from subsequent blow-downs were to be taken and examined.

8.1.2 Some concern was felt during rehearsals that with skeleton watches operating under very difficult conditions, it would not be possible to keep a very effective watch on the evaporator, with consequent risk of making bad water. In the event, however, the evaporator gave no trouble at all.

8.1.3 It was found during practice that the work of sampling continuously would overload both the watchkeepers and the storage space for the half-litre polythene bottles in which the samples were to be taken, particularly as it was necessary that each sample of distillate should be of 1 litre (2 bottles). It was therefore decided for 'HOTSHOT' that sea water samples would be taken at 15 minute intervals for the first three hours, to guard against failure of the Scientific Team's continuous sampling arrangements, but that only a series of five distillate samples, at 15 minute intervals, would be taken, at a time to be ordered by the Scientific Team when activity at the appropriate depth (8 feet) was a maximum. (The sea water samples were in fact taken from the turbo-alternator inlet, there being no sampling cock on the evaporator feed. This was considered immaterial, as the depths of the two inlets were roughly the same). The time interval for distillate sampling was a very rough attempt to ensure that the trial was not made useless by the unknown time required for a particle entering an evaporator to emerge in the distillate.

8.2 'HOTSHOT'

8.2.1 In operation 'HOTSHOT', these arrangements worked satisfactorily, and all samples were taken as arranged. The seawater samples proved unnecessary, as the more elaborate arrangements made by the Scientific Team were satisfactory. Scale samples were taken at each subsequent blow-down for the next 4 days.

8.2.2 Unfortunately, the equipment carried proved inadequate for analysis of the water samples, and this effort was therefore wasted. Examination of the scale samples was carried out by placing a thin layer in a tin under the probe of a Type 1320 monitor. The first sample showed a 'count' of 30 per second compared with 2 per second from a sample extracted from 'A' evaporator, which had been shut down during all the tim when activity might have been present. Unfortunately the presence of mildly active patches of seawater for some time after the trial proper, and the fact that on more detailed examination for comparison purposes (a small pan 'counted' in a lead castle) the activity in the scale proved to be exceedingly patchy, made a reliable estimate of the effects of blowing down impossible. By H + 4 days, activity in the scale seemed to be negligible, though how much of the reduction is attributable to decay, and how much to blowing down it is not possible to estimate.

/ 8.2.3

8.2.3 A subsidiary test was carried out by attempting to test a sample of contaminated seawater by the Contamination Meter No. 1 with liquid counter. This failed, partly because the meter was not sufficiently sensitive, and partly because no calibrating equipment for the counter was available.

8.3 'FLASHLIGHT'

8.3.1 For operation 'FLASHLIGHT' the sampling arrangements were altered somewhat in the light of experience. Intermittent seawater sampling was discarded, the reliability of the more elaborate gear being considered satisfactory, and was confined to two samples, each of 5 litres (10 bottles), taken concurrently with two similar samples of distillate. The first of these samples was to be taken at a time selected as before by the Scientific Team, the second being taken 20 minutes later. Scale samples were to be taken as before.

8.3.2 These arrangements worked satisfactorily, but no results were obtained, for exactly the same reasons as the 'HOTSHOT' trials failed. The revised size of sample was of no more use in this case than the smaller in 'HOTSHOT'. This was partly due to the fact that the seawater contamination was much less in 'FLASHLIGHT' than in 'HOTSHOT'. Again, the scale from "B" evaporator was contaminated, but the presence of mildly active seawater subsequently, and the extreme patchiness of the scale contamination, made estimates of blow-down effectiveness impossible.

8.4 Safety Precautions

8.4.1 The safety limits imposed on drinking water in operation MOSAIC were exceedingly strict. They are shewn in detail in Appendix H. Doubts were expressed at the outset as to whether there was any means on board of positively testing water to these limits, and, as can be inferred from the trial results above, they were only too well founded. In fact, it was found that there was apparently no suitable equipment in the entire Task Force!

8.4.2 As a result, the only precautions that could be taken were as follows:-

a) 'A' Evaporator was not used at any time when seawater activity was suspected.

b) 'B' Evaporator was not used for drinking water unless both the scale from the last blow-down showed negligible activity and it had been running for 48 hours previously on "clean" seawater.

c) No portion of the distilling main which had carried the output from 'B' evaporator was used for distilling to Ship's Tanks until it had been first drained and then flushed with distillate from "clean" seawater for 48 hours.

d) Until 'B' evaporator was declared "clean" all scale-handling at blow-downs was carried out wearing rubber gloves.

8.4.3 The implementation of these precautions was a considerable strain on the ship's resources in both operations, for the following reasons:

/ a)

a) In both cases on return to Monte Bello, the seawater around the islands was reported contaminated, and a General Order was in force forbidding distilling for any purpose or any other use of seawater. This order was relaxed for the anchorage outside the lagoon as soon as H.M.S. DIANA'S seawater probe equipment showed no further contamination, but in both operations this was not until approximately H + 30 hours.

b) The ship's storage capacity of either fresh or feed water did not exceed 36 hours normal consumption.

c) The restrictions on distilling and other uses of seawater coincided neatly with the period when water was required for decontamination, particularly in the machinery spaces.

d) Water boat facilities were negligible. H.M.S. DIANA was, as a special case, permitted to obtain 20 tons from the only available lighter after each operation, but this could only be considered an emergency source.

e) The anchorage was very open, and in anything but flat calm conditions it would in any case have been necessary to keep steam.

f) The declaration of "D-1 day" for 'HOTSHOT' coincided with a severe water crisis owing to two evaporator faults in quick succession.

8.4.4 The time table of restrictions and their removal in the two events was as follows:-

'HOTSHOT':- All distilling to Ship's Tanks stopped - H hour
- 'B' evaporator distilling to feed -
'B' Evaporator stopped on General Order - H+19 hrs.
'B' Evaporator restarted to feed - H+27 hrs.
'A' " " to Ship's Tanks- H+30 hrs.
All restrictions removed from distilling- H+77 hrs.

'FLASHLIGHT':- All distilling to Ship's Tanks stopped- H hour.
- 'B' evaporator distilling to feed -
'B' evaporator stopped on general order - H+21 hrs.
'B' evaporator restarted to feed - H+23 hrs.
'A' evaporator restarted to Ship's Tanks- H+30 hrs.
All restrictions removed from distilling- H+50 hrs.

That restrictions on the use of 'B' evaporator could be relaxed so quickly can only be attributed to the very light contamination which was actually encountered. What the duration of restrictions would have been in the event of heavy fall-out can only be conjectured.

8.5 Discussion, and Conclusions.

8.5.1. It is clear from the general results of operation MOSAIC, as is not unexpected, that contamination of seawater from fall-out does not at once all descend, but that a considerable proportion remains at or near the surface, to be dispersed only slowly. It is therefore impractical to attempt to avoid entirely running evaporators in contaminated seawater.

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8.5.2. It is generally considered that the probability of evaporator feed contamination appearing in the distillate is comparable to the probability of appearance of the salts from seawater. The reduction of contamination might therefore be expected to be in the same proportion, that is, of the order of 2,600 (for the normal chloride content limit for drinking water). This, however, remains to be proved, and trials are therefore desirable. These must be on a full-scale plant, though it may well not be necessary to explode an atomic weapon.

8.5.3. Even if the reduction is normally as great as conjectured above, carryover in relatively large quantities does sometimes occur. The necessity remains therefore for some form of continuous indicating, and if possible recording, device for measurement of radioactive contamination of distillate.

8.5.4. Since it is clear from the results of the trials under report that contamination will enter the evaporator scale, a similar measuring device is required for the feed, to enable suitable precautions to be taken subsequently when blowing down.

8.5.5. The liquid counter for Contamination Meter No.1 is not suitable for this type of measurement. It is apparently far too insensitive (though this obviously depends on what is considered acceptable). Further, the need for separate calibration (for which the necessary equipment has yet to be provided) is against such a dual role for the instrument.

8.5.6. Whatever equipment is devised for this purpose must be capable of distinguishing very low levels of contamination in a relatively enormous gamma background. It must require only a very small quantity of liquid to test. (The seawater probes in H.M.S. DIANA were satisfactory only because they were working in what was, effectively, an infinite contamination field.)

8.5.7. There exists at present no general doctrine on acceptable levels of contamination in drinking water in wartime. This is of great importance, as it is an essential prerequisite of any efforts to develop or use detection apparatus.

8.5.8. Almost the same can be said of peacetime operations, in that as reported above, the acceptable levels for this operation were below the threshold of detection. If these levels are to be retained as limits, it is absolutely essential that all ships involved in the support of atomic weapon tests in any way should be equipped with apparatus capable of testing water to them. As an example of the need for this, H.M.S. DIANA was at one time asked to determine the suitability for drinking of the water in the tanks of H.M.S. ALERT, one of the Headquarters group of ships. Obviously, in view of what is reported above, no conclusion was possible.

8.5.9. The arrangement, common to all 'Daring' class ships, whereby a common pipeline is used for distilling for both feed and drinking water, should be altered, as it would then be possible to make feed water at least when in contaminated seawater, without at the same time causing possible contamination of drinking water.

THER TRIALS.

.1. Salt Water Systems.

9.1.1. The intention of any tests connected with the salt water systems was to find out the tendency for deposits of active material to occur, and to assess their importance if possible. Samples of seawater from various depths throughout the trials were already arranged for by the Scientific Team, although for 'HOTSHOT' a second set of samples was taken in 'B' Boiler Room to guard against failure of the more elaborate apparatus. (See 8.1.3 above). Samples of deposits in all sea inlets were to be taken after the operations, and also samples of any deposits in the condenser discharge water boxes and wherever else deposits might be found. A monitoring survey was to be made around the condensers and circulating water pipes, and was to be extended, according to results found, to other systems.

9.1.2. In the event, results were negligible in either test. In neither test did monitoring near the condensers reveal anything. Activity was just detectable, though somewhat doubtfully, when the probe of a contamination meter was lowered into 'A' condenser inlet water box the day after each event. It is extremely doubtful whether this test was significant. In no case was any removeable deposit found in any of the water boxes, strainer boxes or other accessible points. A coralline deposit was visible in the condenser tubes to some extent, but it was not moveable, and removal of a tube appeared impractical. The only removeable objects found were weed, of which there was more than enough, and fish. Both weeds and fish were mildly active to a contamination meter (about 0.3 mR/Hr at 3 inches), but this information leads nowhere. As a precautionary measure, all work on the interior of seawater systems, changing and cleaning strainers, etc. was carried out in rubber gloves between the day of each event and the ship's departure from Monte Bello (D + 3 after 'HOTSHOT', D + 4 after 'FLASHLIGHT').

9.1.3. It is clear that if any further tests are to succeed in this direction, use must be made of portable detector plates, as in the boiler trial. If the contamination encountered were to be heavy, it would also be worth while to consider the possibility of removing a condenser tube at the earliest opportunity.

9.1.4. It is also clear that unless the fall-out is many thousand times heavier than that encountered in this trial, i.e. very heavy though not necessarily intense, the external wartime hazard from contaminated salt water systems is not likely to be very large of itself.

.2. Diesel Alternator.

9.2.1. It was originally hoped to sample the air entering and gas leaving No.1 Diesel Alternator, which, having a fully trunked air supply, was running on load throughout both trials. This was not however possible, as 'Vacandair' pumps were not obtainable, and no way could be found of attaching a portable dust sampler without dockyard assistance which was not at the time available.

9.2.2. The possibility of internal contamination of the engine could only be dealt with by monitoring after the event. No action was taken after 'HOTSHOT', as labour was not available, and the overall contamination had in any case been very light. After 'FLASHLIGHT' the cylinder heads were removed, but no significant contamination was found by portable meter, and none of the important parts would fit in a lead castle. This could be remedied in a future trial by

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making provision (in labour and material) for cutting up, say, a valve or a piston, and for inserting removeable plates in the inlet and exhaust systems. The inlet air filter (on the engine) was also examined after 'FLASHLIGHT', but showed no significant activity to a portable meter.

9.2.3. To provide for the possibility of contamination by gas leaks from the cylinder heads, a number of steel plates, of the type used in the boiler trials, were arranged around the valve gear covers, and subsequently removed and tested in the same way as the plates from the boiler. Their positions are shown diagrammatically in Fig.12. After operation 'HOTSHOT', none of these showed any appreciable activity. After 'FLASHLIGHT', two indicated signs of activity, but only one to such an extent as to exceed the statistical mean error. Test results are shown in Appendix D, Table D.3. A sample of lubricating oil was also examined, but showed no significant activity.

9.2.4. During the course of both trials, air samples were taken, as near as possible to the cylinder heads, by the Forward Citadel Monitoring Party, using a Type 1195A portable dust sampler. No samples showed significant contamination.

9.2.5. That so little contamination could be found was not altogether unexpected, as the air is ducted to the alternator through a conventional mushroom head in a very well shielded position, and through a very long and devious system of trunking, with a large number of bends. The amount if any of deposition in this trunking could not be assessed with the means available.

9.2.6. The main conclusion to be drawn from these trials is that the possibility of contamination of diesel engines warrants further investigation, since by analogy with the boiler and ventilation trials, it may be assumed that in cases of larger and less well protected intakes, particularly in ships whose main machinery is of this type, a considerable amount of contamination will enter the intakes, and very little indeed emerge from the exhausts. It is possible, however, that insufficient will remain in the engine to make a very serious hazard unless covers are removed or the fall-out exceedingly heavy.

9.2.7. A second conclusion is that there is a definite possibility of contamination of the surroundings of the cylinder heads by gas leakage, even in an engine where much care has been given to ensuring tightness. This possibility could be further investigated at the same time as the question of internal contamination.

9.3. Miscellaneous tests.

Porton Filters.

9.3.1. The 'Porton' filters on the air supply systems of the machinery space ventilated suits were examined, but showed only hardly significant activity to a portable meter. This was partly due to decay, obviously, (the filters could not be examined until D + 4), but would in any case have provided no useful information unless they had been heavily contaminated, in which case it would probably have been worth while removing a sample of the material for laboratory study.

Deck Shielding.

9.3.2. No serious investigation of deck shielding factors was possible, primarily owing to the very small amount of fall-out received. In 'B' Boiler Room the funnel superstructure and presence of the boiler would in any case complicate matters very greatly. In 'A' Engine Room the situation is simpler, but the contamination of the compartment itself made such an investigation impossible after 'HOTSHOT'. After

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'FLASHLIGHT', however, 'A' Engine Room was 'clean'. The upper deck contamination, monitored very shortly before the interior survey (section 4.5) showed dose rates of approximately 4 mR/Hr at approximately 1 ft. from the deck on either side of the deck above, rising to 6 mR/Hr on the top of the torpedo tubes amidships. ("H.M.S. DIANA's report on Operation MOSAIC", Section II, Appendix B.) Comparison of these figures with those obtained inside the Engine Room (section 4.5 above) give tentative indications of factors of the order of 10 at the upper gratings and 20 at the lower, for shielding by deck only, and of 20 at the upper gratings for shielding from deck and torpedo tubes.

4. Miscellaneous Conclusions.

The conclusions below have each been reported more fully in the appropriate sub-section, but are given together here for convenience.

9.4.1. Any further trials of this type should use portable detector plates in the salt water systems, and, should contamination be heavy, would benefit if a condenser tube could be removed for examination. (Para. 9.1.3.)

9.4.2. Unless fall-out is of a fairly heavy order, contaminated salt water systems alone are unlikely to present a major wartime hazard in normal circumstances. (Para. 9.1.4.)

9.4.3. The possibility of internal contamination of diesel engines warrants further investigation, using all the methods used in these trials for 'B' Boiler, and also if possible, cutting up parts from the engine for examination. (Para. 9.2.6.)

9.4.4. There is a definite possibility of contaminating the exteriors of the cylinder heads of even a well-maintained diesel engine by gas leakage. (Para. 9.2.7.)

9.4.5. There is a very rough indication that shielding factors from deposited fall-out over 'A' Engine Room of a 'Daring' Class ship may be of the order of:-

a) At the upper levels - 20 on centreline, reducing to 10 near the sides.

b) At the lower levels - 20 throughout.

(Para. 9.3.2.)

10. CONCLUSIONS.

This section is confined to collating and regrouping the conclusions, and recommendations for future trials, derived in other sections or in the Appendices. References to the appropriate parts of the report are shown, and where the conclusions require detailed explanation, a brief statement only is given.

A conclusion which, by its implications on all sections, it is not appropriate to classify below, is that the contamination experienced in these operations was of a particle size such as not to render invalid comparisons concerning the behaviour of more intense fall-out. (Appendix D, section D.4.)

10.1. General, including Organisation and Training.

It is concluded that:-

10.1.1. Airborne Fall-out can and will enter the intakes of ventilation systems, boilers, diesel engines, etc., even though the intakes are protected by position and construction, and in spite of prewetting. The proportion entering may be expected to be very high. 75% of the outside contamination is a minimum estimate: in the absence of contaminated seawater, a more reasonable figure is very closely approaching 100%. The apparent concentration may far exceed even this figure if contaminated seawater is used for prewetting, causing a fine contaminated mist.
(Sections 6 and 7, Appendix D.)

10.1.2. Of the contaminant entering intakes in this way, virtually none will leave the ship. A very little may leave ventilation exhausts if the system provides a "short-circuit". (Sections 6 and 7.)

10.1.3. Much of the resulting contamination of the interior will be "loose", and easily transferred to the lungs or stomach. This could be a serious hazard, concerning which there is no doctrine applicable to wartime. Guidance to the Fleet is required as to the risk, and its magnitude.
(Sections 4 and 7.)

10.1.4. If loose contamination is accepted to be a hazard, it will cause disorganisation and loss of operational efficiency out of all proportion to its magnitude in terms of external (gamma) dose rate. Respirators and protective clothing may be required in compartments for long periods after fall-out, and if the fall-out contains an appreciable quantity of alpha particle emitters, permanent restrictions may be necessary until full industrial decontamination has been carried out.
(Section 5.)

10.1.5. It is therefore of the highest importance to prevent the occurrence of such contamination wherever possible, by closing down machinery space ventilation systems, trunking air to boilers and diesel engines, etc.

10.1.6. It is desirable that ships should carry reasonable stocks of solvent for decontamination in emergency. Water is not entirely suitable in some parts of machinery spaces, and may in any case not be available when required.
(Section 5.)

10.1.7. Cotton overshoes of the type used by the Atomic Energy Authority are invaluable in preventing the spread of contamination before, during and after decontamination.
(Section 5.)

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10.1.8. The organisation for 'Shelter Stations' within the Engineering Department of a ship should include provision of overshoes and gloves for use by anyone entering a closed-down space during fall-out, and for cleaning the telephones when opening up a space as a matter of routine.
(Section 4.)

10.1.9. There appears to be no doctrine on safe levels of contamination of drinking water in wartime. This is a very serious lack, as it is concluded below that it is not possible to arrange to stop distilling altogether whenever the possibility of contamination exists.
(Section 8.)

10.1.10. The equipment available for peacetime atomic tests in which either loose contamination or contamination of drinking water may require to be assessed must be more closely related to the health physics tolerances laid down, observing that tests requiring a count duration of 20 minutes or more per test are impracticable in these circumstances.
(Appendix H, Section 8.)

10.2. Boilers and Diesel Engines.

It is concluded that:-

10.2.1. Of the contaminant entering the air intakes of a boiler (10.1.1 above), virtually none will leave the funnel. The distribution of deposits may be expected to be of the following order:-

Intakes and blower rooms:-	35-45%.	
Furnace brickwork:-	up to 25%.	(Depends on chemical nature
Tube Nests:-	30 to 50%.	(Dependent on time since cleaning.)
Boiler casings, Uptakes, Funnel:-	up to 5%.	

The uptakes and funnel will be likely to receive more than the air casings.
(Section 6.)

10.2.2. It is clear that the tube nest contaminant is carried mainly by soot. Sootblowing appears to reduce the tube nest contamination by about 50%. It is not certain whether the whole of this reduction is accomplished in one blow, but it is probable that the majority is, subsequent blows having progressively less effect. (Section 6.)

10.2.3. It is clearly essential that in a trunked-air installation no machinery requiring routine inspection or attention, such as the turbines of blowers, should be sited in the blower rooms (i.e. in the airstream at a point where heavy contamination is to be expected). Air tightness of the boiler caskings must be ensured. (Section 6.)

10.2.4. There is a definite possibility of minor contamination of machinery spaces by gas leaks around the cylinder head gear of diesel engines, internal contamination of which is almost certain in view of 10.1.1. above.
(Section 9.)

10.3. Machinery Space Contamination.

It is concluded that:-

10.3.1. Of the contaminant entering the ventilation air intakes (see 10.1.1 above), virtually none will leave the ship, unless there exists a partial "short circuit" of the system. The distribution may be expected to be of the following order:-

/At......

At intake:-	100%.		
		Retained in supply fans and trunking:-	40%
At supply terminal in compt.:-	60%.		
		Retained in compartment:-	45%
At exhaust in compt.:-	15%.		
		Retained in exhaust fans and trunking:-	10%
At upper deck exhaust:-	up to 5%.		

(Section 7.)

10.3.2. The contamination of the supply fans and trunking poses two problems, the first of fan maintenance, the second, and more serious, that of the possible dislodging (e.g. by gunfire) of the deposit at a later stage, with consequent breathing hazard and recontamination of the space, both serious, owing to the large scale of the deposit. (Section 7.)

10.3.3. The contamination deposited will extend throughout the space; surfaces in the neighbourhood of the ventilation airstream may be expected to be about twice or three times as heavily contaminated as those more remote. All surfaces other than lagging and deckheads will probably be more or less equally contaminated. Lagging may be more heavily contaminated because of its porous surface. (Section 7.)

10.3.4. The majority of the contamination will be loose, in the sense that it may easily be transferred via the hands and mouth to the stomach, or via dust to the lungs, nose, etc. This could be a serious hazard, even in quantities too small to give rise to a serious gamma dose rate externally. (Section 7.)

10.3.5. Thorough decontamination of a machinery space is virtually impossible except by major dockyard refit, and even partial decontamination involves such quantities of time, labour and stores, and the precautions involved are so complex and disrupting to operation and maintenance, that great efforts are justified to avoid contamination at all. (Sections 5 and 7.)

10.4. Contamination of Water.

It is concluded that:-

10.4.1. Contamination of the sea by fall-out does not all sink at once. A considerable portion remains at or near the surface, to be dispersed by winds and currents. It is therefore possible to encounter sea contamination in the absence of fall-out. On account of these facts it is not practicable to rely on avoiding contamination of evaporators by ceasing to distil during fall-out. (Section 8.)

10.4.2. It has not been possible to determine the carry-over of contaminant in a ship's evaporators from these trials. Nevertheless, the fact that bulk carry-over of salt can and does occur makes it essential that some form of indicating and preferably recording apparatus be fitted to the distillate output of evaporators for detecting contamination at whatever level may be deemed acceptable. (See also 10.1.9 above.) Some points concerning the detail requirements of such apparatus are made. (Section 8.)

/10.4.3. .....

10.4.3. Contamination from seawater will enter evaporator scale. In order to take suitable precautions when handling the scale (as in blowing down) later, apparatus is necessary to indicate, and preferably to record, contamination of the feed water, independent of the distillate. This is particularly necessary as sea contamination may be met without airborne fall-out (10.4.1 above.). (Section 8.)

10.4.4. The use of the same pipeline to carry evaporator distillate to feed tanks and drinking water tanks should be avoided, as it may well be necessary to accept radioactive contamination of boiler feed water when contamination of the drinking water supply need not be accepted.

10.4.5. It is essential that all ships acting in support of atomic weapon tests in future should carry and be able to use, equipment for testing the suitability of fresh water for drinking, to whatever tolerances may be laid down in the appropriate Health Physics Regulations. (Section 8.)

0.5. Radiac Instruments.

It is concluded that:-

10.5.1. There is at present in service no suitable equipment for ascertaining the extent of loose contamination, or assessing the risk therefrom. If it is accepted that such a hazard exists, some such equipment is essential. Two possible forms for this equipment are suggested. (Section 4.)

10.5.2. The present Contamination Meter No.1 suffers from a number of disadvantages. Some are serious, some not. Those which are serious are:-

a) It appears by the standards of these operations to be far too insensitive for personnel monitoring.

b) It is by any standards too easily 'swamped' by background.

Some suggestions are offered. (For other details, see Section 4.) (Section 4.)

10.5.3. For exactly similar reasons, the Contamination Meter No.1 is unsuitable for use in sea-water and distillate monitoring for evaporators (see 10.4.2 and 3 above). Some suggestions as to requirements for such an instrument are made. (Section 8.)

10.5.4. There is a need for a dose-rate meter of intermediate range between that of the Contamination Meter No.1 and the Survey Meter No.2. The Survey Meter No.3, patt. 6665-110123 is suggested as basically ideal for this purpose. (Section 4.)

10.5.5. The polythene bags now supplied to protect instruments in use from contamination are insufficiently transparent. (Section 4.)

10.5.6. Two small points concerning the behaviour of standard Quartz Fibre dosimeters were noted. These points, though small, could be very misleading to users. (Section 4.)

10.5.7. There appears to be no apparatus available which will test drinking water for purity to the "industrial" tolerances used in these operations. Such apparatus is an essential requirement for ships operating in support of atomic weapon tests, on account of the lingering of seawater contamination in patches. (Section 8.)

10.6. Estimated Wartime Risks.

10.6.1. It appears probable that in the event of passage through heavy, but not extreme, fall-out, the consequent hazard from trunked-air boilers would be of the following order:-

a) The boiler as a whole would be a considerable, though not lethal, hazard to watchkeepers or to personnel in compartments adjacent to the blower rooms or intakes for some time after the event. The hazard to watchkeepers in the boiler room could be appreciably reduced by sootblowing, but great care would be necessary when doing so to prevent danger to personnel or recontamination of the ship.

b) Access to blower rooms or intakes or the furnaces might be a lethal hazard, and would remain a serious "internal hazard" for a long time after the gamma radiation level was reduced to a safe point.

c) Access to any part of the boiler casings would remain a serious "internal" hazard for a very long time, particularly if any significant proportion of alpha-particle emitters were present.

d) Leakage from the air casings could cause serious contamination of the boiler room.

This situation requires further investigation before any more detailed statement is made.
(Section 6.)

10.6.2. In the case of a machinery space contaminated through half its normal ventilation, supplied through a well protected intake, a very rough indication of the expected dose rate would be that in positions ventilated directly might show about the same rate as the prewetted upper deck, and more remote positions rather less than half that figure.
(Section 7.)

10.6.3. It appears likely that unless the fall-out be very heavy, the external gamma radiation hazard from contaminated salt water systems is unlikely to be serious alone.
(Section 9.)

10.6.4. It has not been possible to estimate the wartime hazard from loose contamination or from fresh water contamination in these trials.

10.6.5. There is a very rough indication that the shielding factors from deposited contamination given by 'A' Engine Room of a 'Daring' class ship may be:-

a) At upper levels:- 20 on the centreline, reducing to 10 near the sides.

b) At lower levels:- 20 throughout.
(Section 9.)

10.6.6. There is liable to be a very heavy drain on the ship's fresh water supplies during decontamination after fall-out. In the event of extensive contamination of personnel, or of many decontamination parties being employed, this might well be beyond the ship's capacity to supply.
(Section 5, Appendix H.)

10.7. Recommendations for any future trials.

10.7.1. More experiment is required before the amount of contaminant likely to enter intakes can be properly estimated. Tests /must....

must take into account the possible augmentation of intake contaminant from the prewetting system. It seems unlikely that these trials can be carried out with simulated fall-out. (Section 6.)

10.7.2. The probable internal contamination of diesel engines warrants further investigation, using all the methods employed in the boiler trial (section 6) and, if possible, cutting up parts from the engine for examination. (Section 9.)

10.7.3. In any future trial series of this nature, fuller preparations, including more extensive instrumentation, are required. Preparation must be made for contamination levels very different from that intended. (General and Appendix A.)

10.7.4. In any future trial series of this nature, stocks of protective clothing should be provided sufficient to cater for much more extended use than in these operations. (Section 7.)

10.7.5. Further tests on contamination of salt water systems appear to be necessary. Suggestions for methods are made, but it does not appear that such trials can be carried out with simulant. (Section 9.)

10.7.6. Tests of a full-size evaporator are required to determine the contamination to be expected in the output as a result of feed contamination. The only available approximation at present is to assume carry-over in the same proportion as sea salt. (Section 8.)

10.7.7. In any future trials, less attention need be paid to the boiler casings, but better air sampling is required in all fields. The plate sampling technique should be applied to machinery spaces, diesel engines and salt-water systems. (Sections 6,7 and 9.)

10.7.8. There appears to be satisfactory correlation between the boiler trials here reported and those carried out with chemical tracer in H.M.S. DECOY. It follows that waterborne chemical tracer may satisfactorily be used for future trials, provided means can be found for creating a uniform mist <u>outside</u> the intakes and (if applicable) prewetting, for simulating the use of contaminated prewetting water, and for better means of assessing tube-nest deposits.

11. ACKNOWLEDGEMENTS

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J C Halifax
11th September 1951

A.R.L. Teddington
JCH/PEC/DCP

APPENDIX A

INSTRUMENTS AND EQUIPMENT

It is not intended to give in this appendix an exhaustive list of the ment carried or used in these trials, but only to show the principal s, and to suggest modifications to the list in the event of future trials g contemplated. Nor is it intended to list equipment carried for th control purposes or for trials other than those under report, except e such equipment was used in the conduct of these trials.

It must therefore be emphasised that large quantities of such equip- as film badges, protective clothing, boots, gloves, face masks, over- s, and other items are required in this type of operation in addition quipment specifically intended for trials.

All dose rate meters were calibrated before each operation, and all ings quoted throughout the report have been corrected accordingly.

The principal instruments and equipment available for trials purposes as follows:-

a) Portable

6665-110107	Meter, Contamination, No.1 (Battery operated)	2 in No. (1 with liquid counter)
" -110130	Meter, Survey, Radiac No.2	1 in No.
" -110123	" " " No.3 (Borrowed from A.W.R.E.)	1 in No.
-	Portable dust sampling unit, type 1195A (with extension hose for suction)	1 in No.
	Quartz Fibre Dosimeters:-	
6665-110001	No.1 (0-0.5 R)	
" -110101	No.2 (0-5 R) For personnel control	1 in No.
	- " - For trials purposes	27 in No.
		4 in No.

b) Fixed

Type S.C 1. "Vacandair" suction pumps, by Aerosol Products Ltd. with filter holders to take filters for dust sampling units, and 10 ft. of rubber suction hose each. 2 in No.

c) Equipment used by A.R.L. Scientific Team for examination of samples

Standard lead castle, with type 2B2 G-M tube coupled to Ecko type N530C Automatic Scaler.
Type 1320C portable ratemeter.
Type 1196B portable scintillation counterhead.
Type 1257C portable monitor counter.

d) Miscellaneous equipment

Steel plates, 3" x 3" x 1/16"	200 in No.
Firebrick samples, 3" x 3" x ½"	26 in No.
Lagging cloth samples, 3" x 3"	12 in No.
Plastic bottles, ½ litre	60 in No.

The major items of this equipment were distributed as follows:-

/ 'A'

'A' Engine Room

Contamination Meter No. 1.
Dust sampling unit (part time only)
Quartz fibre dosimeter No.2A, 1 in No.

'B' Boiler Room:-

Survey Meter No. 3.
Contamination meter No. 1, with liquid counter ("HOTSHOT" only).
Dust sampling unit (part time only)
Quartz fibre dosimeters No.2A, 3 in No.

Engineer's Workshop:-

Quartz fibre dosimeter No.1, 1 in No.

'B' Boiler air intakes:-

'Vacandair' suction pump.

'B' Funnel:-

'Vacandair' suction pump, connected via cooled pipe to sampling point approx. 2 ft. in from side of funnel, 12 ft. above economiser.

A.6 Air sampling at the cylinder head of No. 1 Diesel Alternator was carried out by the Forward Citadel Air Monitoring Party using a type 1195A dust sampler. (Not shown in the list above).

A.7 The Contamination meter was removed from 'B' Boiler Room for 'FLASHLIGHT' as it had proved useless for liquid sampling and it was considered that the Survey Meter No. 3 would be adequate for ratemeter monitoring during the event.

A.8 The Survey Meter No.2~~3~~ was not used, as the lowest reliable reading with this instrument is of the order of 300 mR/Hr, which is three times the rate at which it had been decided to take steps to steam out of the fall-out, and in any case the Survey Meter No. 3 reads up to 3R/Hr.

A.9 Had the full intended fall-out been encountered, the Contamination Meter in the Engine Room would have been inadequate. However, there was only one Survey Meter No. 3, and it seemed probable that the Boiler Room would show the higher dose rates. A temporary transfer of the Boiler Room instrument to the Engine Room had been arranged if required. For any further trials, a second Survey Meter No. 3 is essential.

A.10 Arrangements for air sampling were handicapped by the fact that only one sampler was available, which therefore had to be transferred from space to space. This, with a very limited watch, was not easy to arrange, and the number of samples which could be taken was therefore severely restricted, especially in view of the time required to set up, operate and dismantle the sampler when wearing protective clothing.

A.11 As a result of the experience in air sampling in this operation, it is considered that in any future trials of contamination by ventilation, it is desirable to arrange for four continuous sampling points in a single compartment's ventilation system. (See also section 10). Samplers of the 'Vacandair' type would be excellent.

.12 It had been hoped to obtain some more 'Vacandair' pumps to sample the nlet and exhaust of the diesel alternator, but the liquidation of the anufacturers prevented this.

.13 It was initially intended to use many more Quartz Fibre Dosimeters, to he extent that each man would carry a No. 1 and a No.2A, and that each of t least 12 positions would be supplied with the same, thereby providing for wider range of possible doses. Sufficient dosimeters, particularly the o. 1's were not, however available, and in the event the fall-out was so ight that this did not matter. For any future trials, however, it is esirable that the number of dosimeters be increased.

.14 As a guide for any such future trials, it is considered that the list f principal items (para. A.3 above) required to carry out the same tests s were attempted in the trials under report should be:-

a) Portable

Contamination Meters, Battery operated	- 3	(1 for after action survey and spare)
Survey Meters, No. 3	- 3	(- " -)
Dust Samplers, type 1195A	- 3	
Quartz Fibre Dosimeters No. 1	- 40	
" " " No. 2	- 40	

b) Fixed

'Vacandair' suction pumps - 13
(6 for boiler, 3 for diesel alternator, and 4 for E.R. Ventilation)

The equipment listed in para. A.3 above at (c) and (d) should be unchanged, except that more steel plates, lagging samples and brick samples could well have been used.

.15 Although the experiences with protective clothing have been more fully eported elsewhere ("H.M.S. DIANA'S report on Operation MOSAIC", Section IVB), t is desirable to note here the total numbers of suits of various types used, s a guide to the future.

hese were:-

Air-ventilated suits - 18
Gaberdine protective suits, 'HURRICANE' type - 24 - (A.W.R.E. suits would have been preferred, as the 'HURRICANE' type has no hood)
Cotton protective suits, borrowed from A.W.R.E. - 20.

All the above suits were at one time or another required. Although the umber was thus sufficient for this operation, it is probable that if the ull expected contamination had been encountered, and certainly if any suits ad been so contaminated as to require more than sea-water washing afterwards, here would have been a shortage. A larger number is therefore required for ny other similar operation.

APPENDIX B

RESULTS OF TESTS FOR LOOSE CONTAMINATION

B.1 In this Appendix are shown the results of smear tests for monitoring purposes (see also Section 4), in the machinery spaces and on outside machinery. These tests formed the basis for the work of decontamination described in Section 5, and also assisted in the assessment of contamination by ventilation (Section 7). Discussion of the results will be found in these sections, except for certain points of common ground.

B.2 All results are shown with the time at which they were obtained, as in all comparable cases, these times are sufficiently close to avoid the need for correction for decay, in view of the approximate nature of any comparison which can legitimately be made.

B.3 All smear tests were made by rubbing a Whatman No. 1 (5.5cm) filter paper over an area of approximately 30 in^2 of the surfaces to be tested. The papers were "counted" for 100 seconds on Shelf I of a standard lead castle (2B2 G-M tube) coupled to an Ecko N530C automatic scaler. The background count has been subtracted from, and 'dead time' (500 microseconds) allowance added to all counts shown. All tests were taken to the same operator, by minimise as far as possible variations of smearing pressure and coverage.

B.4 No figures for statistical accuracy are shown. As a guide, it may be said that the standard deviation of any "count" is equal to the square root of the "count". In all cases recorded the background was of the order of 50 to 70 counts in 100 seconds, i.e. a standard deviation of 8. Corrected counts of less than this value are therefore statistically insignificant, an must be regarded with some suspicion if less than about 12.

B.5 The equipment and method of counting used give a collection efficiency of approximately 60% and a counter efficiency of approximately 20%. On this basis, the tolerance laid down for loose contamination (Appendix H) in these trials is equivalent to a count of 4 in 100 seconds from any smear.

B.6 It is worthy of note that, even if it is assumed that the smearing pressure and coverage are exactly identical for all tests (a quite ridiculou assumption), the tolerance for loose contamination is less than the standard deviation of a background count. This, while by no means invalidating these tests as a means of assessing loose contamination, indicates a need fo a much greater degree of realism in establishing tolerances for this kind of work. A similar lack of realism was observed in the tolerance for water contamination (Section 8.4, q.v.). (See Appendix H for detailed comment).

B.7 As a very approximate indication of the relation between 'loose' (as defined in health physics regulations) and 'fixed' contamination, counts of 100 seconds taken from (a) a 3-inch square plate fixed to the side of the boiler air intakes (plate No. 88 - ref. Appendix C) and (b) a smear taken from the surface immediately adjacent to the plate were:-

(a) From the plate:- 123,550 at H + 50 hrs.

(b) From the smear:- 928 at H + 50 hrs.

From this it seems reasonable to suppose that very little of the depos contamination in these tests was 'loose', as defined by smear tests, though it is equally reasonable to suppose that very much more is loose in the sen that it will be removed by repeated handling, or normal wear and tear. This is to some extent confirmed by comparison of the test results on equipment

/ which

which had been much handled during the trials, and those on equipment which had not.

The conclusion, therefore, must be that the 'smear test' while giving a comparative indication of loose contamination levels, can very much under-estimate the actual amount of contamination liable to transference.

/ TABLE B.1

TABLE B.1.

MONITORING SURVEY, 'HOTSHOT'

Compartment, and time of counting	Position	Corrected Count, (100 Secs)	Remarks
'A' Boiler Room (H + 13 hrs.)	Access ladder treads	13	
	Control Platform deck plates	190	
	Deck plates by Evaporator	10	Not significant
	" " by Turbo Alternator	-	
	Access Ladder Handrails	10	Not significant
	Gallery Handrails	-	
	Register desk	-	
	Lagging on Turbo Alternator	-	
	" " F.F.O. Pump	-	
	Ventilation Inlet terminal	10	Not significant
'A' Engine Room (H + 14 hrs.)	Access Ladder Treads	20,056	
	Starting Platform Plates	8,650	
	Lower Ladder treads	8,854	
	Lower Platform Plates	9,745	Wet from prewetti[ng]
	Access Ladder Handrails	689	Much handled
	Handrails in airstream	15,597	
	Lagging in airstream	18,993	
	Control gear in airstream	17,010	
	Handrails not in "	1,040	Much handled
	Lagging " " "	7,472	
	Control gear not in "	6,810	
	Telephone Control Box	283	Much handled
'B' Boiler Room (H + 14 hrs.)	Upper Ladder Treads	34,486	
	Lower " "	26,000	
	Control Platform Deck Plates	10,593	
	Deck plates by Turbo-Alternator	33,350	
	Upper Ladder Handrails	271	
	Lower " "	9,258	
	Handwheels in Control Position, not in airstream	108	Much handled
	Handhweels by Evaporator, not in airstream	10,686	
	Handwheels by Turbo Alternator, in airstream	21,670	
	Sprayer operating gear	2,200	Much handled
	Lagging of pipes in airstream	22,656	
	Lagging of feed pump, well out of airstream	544	
'B' Funnel Casing (forms vent exhaust) (H + 16 hrs.)	Deck Plating	539	
	Outboard Bulkheads	2,536	
	Inboard " (Funnel plating)	1.258	
'B' Engine Room (H + 15 hrs.)	Access Ladder Treads	128	
	Starting Platform Plates	14	
	Lower Ladder Treads	288	
	Lower Platform Plates	38	
	Access Ladder Handrails	8	Not significant
	Starting Platform Handwheels	-	
	Lower Ladder Handrails	-	
	Handwheels in air stream	-	
	Lagging in air stream	-	

TABLE B.2.

MONITORING SURVEY, 'FLASHLIGHT'

Results are only shown for 'A' Engine Room and 'B' Boiler Room, there being no significant contamination in other spaces.

Compartment, and time of counting	Position	Corrected Count, (100 secs)	Remarks
'A' Engine Room (H + 15 hrs.)	Starting Platform Plates	57	Wet from prewetting
	Lower Platform Plates	25	" " "
	Register Desk (in airstream)	20	Much handled
	Access Ladder handrails	30	" "
	Other handrails (in airstream)	-	
	Gauge Boards (in airstream)	-	
	Lagging in way of airstream,	-	
	Telephone Mouthpiece	17	Probably from Respirators
'B' Boiler Room (H + 16 hrs.)	Control Platform Plates	617	
	Lower Ladder treads	122	
	" " handrails	51	Much handled
	Pipe Lagging in way of airstream	-	
	Pump Lagging not in airstream	-	
	Handwheels in airstream	42	Much handled
	Sprayer operating gear	43	Much handled
	Telephone mouthpiece	128	Probably from Respirators

TABLE B.3.

SHEAR TESTS FROM SYRENS - 'FLASHLIGHT'

Position	Time of Counting	Corrected Count (100 secs)
Port Syren, Bell	H + 7 days, 7 hrs.	118
" " Body	- " -	186
" " Platform	- " -	149
" " Ladder Rungs	- " -	43
Stbd. Syren, Bell	- " -	21
" " Body	- " -	20
" " Platform	- " -	103
" " Ladder Rungs	- " -	53

APPENDIX C.

RESULTS OF TESTS ON SAMPLES FROM 'B' BOILER.

C.1. This Appendix shows the results of tests carried out on all samples taken from the air/gas path of 'B' Boiler in both phases of the operation. The positions of the samples are shewn in Figs. 2-10, the evaluation of the test results in Appendix G.

C.2. All plate samples were of bright steel, 3" x 3" x 1/16". Their positions are shewn in Figs. 2-9. All tests on these plates were made by 'counting' the plates, which were encased in thin polythene bags for the purpose, in the same way as smear tests, that is on Shelf I (Collection efficiency 60%) of a standard lead castle.

C.3. Brick samples were of standard firebrick as used in H.M.S. DIANA's boilers. They were initially 3" x 3" x ½", but when removed for testing had been reduced to approximately 3" x 1½". These were placed in polythene bags and tested in the same way as the steel plates, though in some cases the samples were placed in Shelf II of the castle (Collection efficiency 30%) in error. In these cases the results shown have been adjusted to be comparable with those for the other tests. Brick sample positions are shown in Fig. 10.

C.4. Lagging samples were untreated asbestos cloth, 2" x 2" (to allow for the more ragged edges when placing in the castle), and were tested, in polythene bags, on Shelf I of the castle as for the other samples.

C.5. Soot samples were collected in tins, and tested by placing a full (level) planchette (a small metal dish) in the socket provided in the castle Shelf (I). It was found that the weight of soot thus tested was surprisingly uniform, being within 10% of 600 mgm.

C.6. After 'FLASHLIGHT', a brickdust sample was obtained from the water wall brickwork by rubbing with a gloved hand above a tin. This sample was tested for α activity from a level dish in a scintillation counter type 1196B, Monitor type 1257C. Smear tests, taken as described in Appendix B, from the blades and casing of the Port Forward Blower were similarly examined.

C.7. The filters from the 'Vacandair' pumps in the air intake and funnel were tested on Shelf I of the lead castle. Each filter consisted of two parts, tested separately. A paper filter, as supplied for the type 1195A dust sampler, was used, backed up by a coarser filter of glass cloth. The retention characteristics are unfortunately not fully known. A "collection efficiency" of 60% is given, and it is claimed that almost all of the 40% not collected is in the size range below 1 micron diameter, which is in fact unimportant in this context.

C.8. Dead time (500 microseconds) has been allowed for in all counts, and all comparable tests have been adjusted for decay. That is, for each operation, all beta-gamma tests of air filters, plates, bricks, lagging and soot samples have been corrected to the same time datum. The time data for the two operations are not the same, but this is of no importance, as the apparent decay rates differ.

C.9. Test results from plates, bricks and lagging samples are shewn in Tables C.1 ('HOTSHOT') and C.2 ('FLASHLIGHT'). Tests from the intake and uptake filters in both trials are shewn in Table C.3, and miscellaneous test results are shewn in Table C.4.

/C.10. .....

.10. For each test from the plate, lagging or brick samples is shewn the itatistical "mean error". This figure, determined from the square roots of :he test and background counts, and adjusted pro rata for decay, shows the .imits within which two-thirds of a statistical sufficiency of such counts should lie. In a number of cases it will be seen that the 'mean error' exceeds the actual count. This does not necessarily mean that the activity ras not statistically significant (this would only be so if the mean error of the background alone exceeded the actual count), but may be taken to indicate that the activity was of "trace" magnitude at the time of testing, ind accuracy of estimation is therefore very low indeed. Such counts have iot, however, been noted as 'trace only', as in many cases the repetition of similar results in a number of adjacent positions justifies the assump- :ion of a somewhat greater accuracy for the mean.

/Table C.1. ....

TABLE C.1.

TESTS ON PLATE AND BRICK SAMPLES - 'HOTSHOT'.

Time Datum: H + 120 hrs. (1200, 21st May).

Plate No.	Count.	Mean Error.	Location of Rate.
15	31	15	Back casing - Port upper.
20	29	15	" " - " centre.
21	162	22	" " - " lower.
29	58	17	Front " - S/H Furnace.
31	0	-	" " - " "
32	21	15	" " - Saturated Furnace.
62	361	27	Uptake, below gas sampler.
63	235	24	Funnel, above " " .
72	8	14	Starb'd Blower Room - Aft.
73	164	22	" Intake trunking.
74	0	-	" " " .
75	50	16	" " " .
76	8300	460	" " " .
77	7200	380	" " " .
78	6	15	" Blower Room - For'd.
79	379	28	" " " - " .
80	17	16	" " " - Aft.
81	625	240	" " " - For'd.
83	0	-	" " " - " .
84	42	17	" " " - Aft.
85	32	17	" " " - " .
86	1591	48	Port intake trunking.
87	3878	72	" " "
88	61,100	310	" " " .
89	873	39	" Blower Room - For'd.
90	154	22	" " " - " .
91	96	19	" " " - " .
92	131	20	" " " - Aft.
93	52	17	" " " - " .
94	23	16	" " " - " .
Brick No.			
1	76	22	Saturated furnace - front, centre.
2	80	22	" " - back, centre.
3	67	21	" " - middle, right centre.
4	47	20	Superheater furnace - front, centre.
5	77	22	" " - back, centre.
6	87	23	" " - middle, left.

/Table C.2. ....

TABLE C.2.

TESTS ON PLATE, BRICK AND LAGGING SAMPLES - 'FLASHLIGHT'.

Time Datum: H + 153 hrs. (1900, 25th June).

Sample No. Plate No.	Count.	Mean Error.	Location of Sample.
1	0	-	Side Casing - For'd.
2	40	50	" " - "
3	0	-	" " - "
4	0	-	" " - "
5	0	-	" " - "
6	0	-	" " - Aft.
7	94	60	" " - " .
8	25	52	" " - " .
9	8	52	" " - " .
10	0	-	" " - " .
11	32	56	Back Casing - Port upper.
12	72	56	" " - " " .
13	210	68	" " - " " .
14	43	50	" " - " " .
115	0	-	" " - " " .
16	0	-	" " - " " .
17	0	-	" " - " lower.
18	28	28	" " - " " .
19	63	28	" " - " " .
120	0	-	" " - " " .
121	0	-	" " - " " .
22	24	40	" " - " " .
23	0	-	Bottom Casing, Superheater furnace.
24	83	56	" " , " " .
25	0	-	" " , " " .
26	4	52	" " , " " .
27	0	-	" " , " " .
28	0	-	" " , " " .
129	0	-	Front Casing, Superheater furnace.
30	16	56	" " , " " .
131	100	60	" " , " " .
132	84	60	" " , Saturated " .
33	53	60	" " , " " .
34	75	60	" " , " " .
35	28	52	" " , " " .
36	4	56	Bottom Casing, Saturated furnace.
37	20	56	" " , " " .
38	16	56	" " , " " .
39	89	63	" " , " " .
40	20	55	" " , " " .
41	49	60	" " , " " .
42	76	62	" " , " " .
43	61	60	Back Casing, Starboard lower.
44	20	54	" " , " " .
45	8	47	" " , " " .
46	16	56	" " , " " .
47	0	-	" " , " upper.
48	0	-	" " , " " .
49	0	-	" " , " " .
50	33	52	" " , " " .
51	35	56	" " , " " .
52	24	52	" " , " " .
53	24	52	" " , " " .
54	4	48	" " , " lower.

Continued on further sheets (II & III).

TABLE C.2 - Contd. - Sheet II.

Sample No. Plate No.	Count.	Mean Error.	Location of Sample.
55	94	48	Uptake, below gas sampler.
56	84	48	" , " " " .
57	14	48	" , " " " .
58	38	48	" , " " " .
59	77	48	" , " " " .
60	104	48	" , " " " .
61	14	48	" , " " " .
162	88	48	" , " " " .
163	88	48	Funnel, above gas sampler.
64	73	48	" , " " " .
65	84	48	" , " " " .
66	79	48	" , " " " .
67	104	48	" , " " " .
68	37	48	" , " " " .
69	31	48	" , " " " .
70	62	48	" , " " " .
71	0	-	" , " " " .
151	0	-	Port Blower Room - Aft End.
152	0	-	" " " - " " .
153	0	-	" " " - " " .
154	0	-	" " " - " " .
155	0	-	" " " - " " .
156	0	-	" " " - " " .
157	0	-	" " " - " " .
158	34	15	" " " - " " .
159	34	15	" " " - Centre section.
160	26	14	" " " - Aft End.
161	36	15	" " " - " " .
164	55	22	" " " - Centre section.
165	25	14	" " " - " " .
166	22	14	" " " - " " .
167	41	16	" " " - " " .
168	3700	61	" " " - " " .
169	7	13	" " " - Forward End.
170	0	-	" " " - " " .
171	16	14	" " " - " " .
172	14	14	" " " - " " .
173	467	34	" " " - " " .
174	27,500	160	Port Intake Trunking.
175	3,238	63	" " " .
176	8,700	92	" " " .
177	4,234	65	" " " .
178	24	11	" " " .
179	26,460	160	" " " .
180	54	16	" " " .
181	21	14	" " " .
182	149	25	Starboard Intake Trunking.
183	34	15	" " " .
184	728	30	" " " .
185	659	27	" Blower Room - Forward End.
186	40	16	" " " - " "
187	597	32	" " " - " "
188	108	19	" " " - " "
189	29	14	" " " - " "
190	27	15	" " " - " "

Continued on Sheet III.

TABLE C.2 - Contd. - Sheet III.

ample No. Plate No.	Count.	Mean Error.	Location of Sample.
191	27	15	Starboard Blower Room - Forward End
192	35	15	" " " - Centre Sec[n].
193	28	14	" " " - " "
194	36	15	" " " - " "
195	21	14	" " " - " "
196	0	-	" " "
197	46	16	" " " - Aft End.
198	37	15	" " " - " "
199	59	16	" " " - " "
200	21	14	" " " - " "
agging No.			
A	67	17	Above Port Aft Blower Turbine.
B	17,660	132	" " Forward Blower Turbine.
C	45	16	On Port Forward Blower Turbine Casing
D	27	15	On Port Aft " " "
rick No.			
1	207	36	Saturated furnace, Back, Centreline.
2	212	37	" " , Middle, Left side
3	171	30	" " , " , " centre
4	186	32	" " , " , Right "
5	171	30	" " , " , " side
6	216	37	" " , Front, centreline
7	289	50	Superheater furnace, Back, centreline
8	207	36	" " ,Middle, left side
9	155	27	" " , " centreline
10	228	39	" " , " Right side

/Table C.3. ....

TABLE C.3.

BOILER AIR AND GAS FILTERS

Trial.	Filter	Count (100 Sec)	Time Datum	Remarks
HOTSHOT	Intake, Paper	40,842	H+120 hrs.	Total Intake Count 40842
	" , Glass	0	"	
	Uptake, Paper	4	"	Total not significant.
	" , Glass	0	"	
FLASHLIGHT	Intake, Paper	914	H+153 hrs.	Vacandair Pump Diaphragm fault.
	" , Glass	28	"	
	Uptake, Paper	3	"	Total not significant.
	" , Glass	0	"	

NOTE: Both Intake and Uptake pumps were operated under similar conditions, e.g. in both cases the suction tube length was 10 ft. Measured throughput was approximately the same for both pumps, 0.42 ft^3/mm.

/Table C.4. ......

TABLE C.4.

MISCELLANEOUS BOILER SAMPLES.

SOOT. - Wt. of samples, 0.60 gm.

Operation	Soot from:	Corrected Count (100 Sec)	Time Datum	Remarks.
HOTSHOT	Furnace floor Main Tube Bank Above Economiser	0 243 200	H+120 hrs. " "	Before soot blowing " " " " " "
FLASHLIGHT	Furnace floor. Main Tube Bank Above Economiser.	Insignificant 60 32	H+153 hrs. " "	After soot blowing " " " " " "

BRICKDUST, α CONTAMINATION.

Operation:- FLASHLIGHT.
Sample:- Brickdust from Water Wall.
Examined by:- 1196B Scintillation Counter.
Time:- H + 330 hrs.
Count:- 71 in $6\frac{3}{4}$ hrs. (background subtracted).

BLOWERS, CONTAMINATION.

Operation:- FLASHLIGHT.
Samples:- Smear Tests from 'B' Port For'd Blower.
Examined by:- 1196B Scintillation Counter for α,
2B 2 geiger for β/γ
Time:- H + 330 hrs.

All Counts have background subtracted.

Sample from:	α Count and time.	β/γ Count and time.
Blades Casing	330 in $16\frac{1}{2}$ hours -	81 in 100 secs. Insignificant.

NOTE: The β/γ Count is approximately equivalent to a count of 318 at H + 153 hrs.

APPENDIX D

MISCELLANEOUS TESTS AND DATA

D.1 General

D.1.1 This Appendix contains the results of tests on Engine Room ventilation air, sample plates, etc. from the Engine Room and the surrounds of the Diesel Alternator, and such information as can be obtained on particle size and comparative intensity of fall-out outside the prewetting from the samples collected by the Scientific Team.

D.2 Air Samples

D.2.1 Table D.1 shows the results of tests on ventilation air samples. Only those tests to show a conclusive result are listed. Results shewn are fully corrected counts on filters from a type 1195A dust sampler. The filter characteristics are not fully known, but, as reported in Appendix C (para. C.7), it is claimed that most of the material passed is below 1 micron in diameter, and is therefore, in view of the particle sizes measured on the forecastle (D.4 below) unimportant in this context.

D.3 Engine Room and Diesel Alternator Samples

D.3.1 Table D.2 shows the corrected counts from plates and lagging samples in 'A' Engine Room during 'FLASHLIGHT'. The plates and lagging samples, and their testing, were identical to those used in the boiler trial. (See Appendix C, paras. C.2 and C.4) Table D.3 shows the results of tests on similar plates around the cylinder heads of the diesel alternator.

D.3.2 The positions of these samples are briefly described in the tables, and may be seen more clearly from fig. 11 (Engine Room samples) and fig. 12 (Diesel Alternator samples).

D.4 Particle Size

D.4.1 Table D.4 shows the results of tests on the particle size of the fall-out encountered during the two events. As a comparison, a result is also shown from a position very close (4 miles) to ground zero. These results are obtained from counts on the slides of cascade impactors sited with their entries horizontal, i.e. approximately directed into the prevailing wind.

D.4.2 An important deduction from these results is that the fall-out encountered by the ship was not extreme in the sense of rendering the trials useless for comparison with heavier fall-out, since the particle size encountered closer to ground zero was apparently smaller in the great majority of the material.

D.5 Comparison of concentration outside prewetting to intakes

D.5.1 Table D.5 shows, in tabular form, all counts comparable with those from the boiler intake filters (Appendix C, and also shown in this table). Some are from the cascade impactors, and some from filters with air entry at different angles. In all cases the air throughput was the same. All counts for a given operation have been corrected for decay to the same time datum. The counts from the boiler intakes must be considered as underestimates, as the filters were sited to minimise the impaction effect, and, as can be seen

/ from

from figs. 3 and 4, were unlikely to receive the larger particles in any case.

D.5.2 It is considered that the great majority of the material arriving on the open filters either blew off or fell off, according to the plane of the filter paper. The impactor counts therefore offer the best results, as the impactors were backed by a filter reputed to retain particles of less than 0.1 micron diameter.

D.5.3 From these it appears that if, as seems likely from the boiler trial (see Appendix G), boiler intake in 'FLASHLIGHT' was about 85% of that in 'HOTSHOT', no conclusive assessment of the relative contamination of intake air to air outside prewetting is possible. On the other hand, while it is not unreasonable to suppose that a large proportion of the material arriving fell off or was blown off the exposed filters, it is quite unreasonable to assume this for the impactors, which were operating with their intakes directed into the mean wind.

D.5.4 It is therefore reasonable to assume that a very large proportion of the 'outside' contamination entered the intakes. In fact, it seems quite unreasonable to assume that less than 75% entered, as this would imply an impactor "collection efficiency" of only one third!

D.5.5 It is in any case known that water spray filtration is largely ineffective for particle sizes below 25 microns. An assumed entry of 100% in this case is therefore not unreasonable.

D.5.6 It is, of course possible for the boiler intakes to have received an effective contaminant concentration larger than that outside the prewetting, due to augmentation from the prewetting itself. That this augmentation was considerable in this case is however doubtful, as no prewetting appeared in the boiler room ventilation, the intakes of which are immediately in front of the boiler intakes. It is, however, a reasonable conclusion that the possibility of the apparent concentration entering the boiler far exceeding that in the open air must be borne in mind.

D.5.7 It seems therefore reasonable to conclude that to estimate the effective contaminant concentration in the intakes from that in the open air outside the prewetting:-

a) It is not reasonable to use a figure below about 75%.

b) The proportion in these trials was probably about 100%.

c) The possibility of augmentation by contaminated mist from the prewetting is not remote, even up to an apparent proportion of 280%.

/ TABLE D.1.

TABLE D.1.

TESTS ON VENTILATION AIR SAMPLES

Operation	Sample from, and time	Corrected Count (100 secs)	Mean Error	Time counted (from H hr.)
HOTSHOT	'B' Boiler Room Supply Terminal, 2000	103	24	9 hrs.
"	'A' Engine Room Supply Terminal, 2015	115	24	9 hrs.
"	'A' Engine Room Exhaust Terminal, 2030	63	22	9 hrs.

Note:- Corrected counts have been adjusted pro rata for differences in sampler throughput, as shown by anemometer readings, to a standard throughput of 9 $ft.^3$.

/ TABLE D.2.

TABLE D.2.

TESTS ON SAMPLES FROM 'A' ENGINE ROOM
- OPERATION 'FLASHLIGHT' -
- TIME DATUM : H + 153 hrs. (1900, 25th June) -

..mple No.	Count	Mean Error	Location of Sample
..ate No.			
101	119	68	Aft end of Starting Platform plates.
102	114	67	Foot of access Ladder.
103	51	65	Upper gratings, Port For'd. Corner.
104	0	-	Air Compr. Cyl. head. - in way of ventilation.
105	35	36	Upper gratings, Port Aft Corner.
106	16	48	" " Centreline, Aft.
107	0	-	" " Stbd. Aft Corner.
108	0	-	" " Stbd. midships.
109	609	84	" " Stbd. For'd. corner.
110	0	-	On For'd. foot of L.P. Turbine.
111	83	48	Upper gratings, Centreline, midships.
112	0	-	Centreline gauge board.
113	0	-	Main gauge board.
114	0	-	For'd. bulkhead, centreline, upper level.
116	35	56	Upper gratings, Port, midships.
117	0	-	On main circulator turbine.
118	164	16	Lower platforms, Port For'd. corner.
119	142	60	" " Port Aft corner.
122	0	-	Aft Bulkhead, Port, Lower level.
123	0	-	Lower platforms, centreline, aft end.
124	23	15	" " centreline, midships.
125	0	-	" " Stbd. Aft corner.
126	0	-	Top of main gearcase.
127	0	-	Top of air ejector.
..gging			
E	0	-	Piping on For'd. bulkhead, centreline, upper level.
F	0	-	Piping on centreline, for'd. of midships., upper level.
G	0	-	For'd. astern turbine nozzle box.
H	0	-	Centreline, midships, upper level
J	0	-	Piping in Port Aft corner, lower level.
K	0	-	" on centreline aft, lower level.
L	0	-	" " " midships, lower level.
M	0	-	For'd. end of L.P. Turbine.

/ TABLE D.3

TABLE D.3.

TESTS ON PLATES FROM DIESEL ALTERNATOR
TIME DATE:- HOTSHOT + 12 hrs., FLASHLIGHT + 153 hrs.

Plate No.	HOTSHOT		FLASHLIGHT	
	Count	Mean Error	Count	Mean Error
95	0	-	0	-
96	0	-	9	14
97	0	-	0	-
98	0	-	21	14
99	0	-	0	-

TABLE D.4.

PARTICLE SIZE RESULTS
- OUTSIDE PREWETTING -

Operation:-	HOTSHOT		FLASHLIGHT
Particle Size	Close to G.Z. % of total	'DIANA'	'DIANA'
Median Diam. 18μ (Size range, say, over 7μ)	5	99	2
" " 5μ (" " " 3-7μ)	Trace	1	98
" " 2μ (" " " 1-3μ)	0	Trace	Trace
" " 0.6μ (" " " 0.5-1μ)	95	Trace	Trace
Smaller (Say, below 0.5μ)	0	0	Insignificant

TABLE D.5.

CONTAMINATION OUTSIDE PREWETTING

Total Count From	Air entry Angle to horizontal	HOTSHOT (H + 120 hrs.)	FLASHLIGHT (F + 153 hrs.)
Total Air Filter	30° Approx.	1930	4000
" " "	" "	6500	-
" " "	90° "	-	5
Cascade Impactor	0° "	18450	9500
Boiler Intake	-	40842	Pump failed

APPENDIX E

MONITORING DURING FALL-OUT
POSITIONS AND RESULTS

As reported in Section 4.2, positions for ratemeter monitoring during l-out had to be severely limited in number. In addition, the length of e attached to the air-ventilated suits imposed a considerable restriction the positions which could be reached wearing this equipment.

In 'B' Boiler Room, monitoring positions were selected primarily to e warning of any heavy build-up of deposits inside the boiler, or of ly high dose-rates at the watchkeeping positions. Owing to the layout the space, and of the superstructure above it, it was not practicable to estigate upper deck shielding. Quartz fibre Dosimeters were sited at itions normally occupied by watchkeepers, but no doses were recorded in ner test. Details of the positions selected are shown in Table E.1, and results obtained in 'FLASHLIGHT' in Table E.3. No results were obtained 'HOTSHOT' as the instrument (which was only obtained from A.W.R.E. the vious evening) was found during the trial to have a defective switch tact on the lowest range and a faulty battery.

In 'A' Engine Room, the chance of internal contamination of machinery very much less, being virtually confined to the condenser, and there therefore more scope for investigating the results of space contamination /or deck shielding. Accordingly, five positions at upper platform level e selected to indicate the dose rate at the centre of the compartment and variation forward and aft, to Port and to Starboard of this point. It not possible to reach corresponding positions at lower platform level, positions at this level were chosen to indicate any build-up of deposits the condenser. A quartz fibre Dosimeter was suspended in the middle of starting platform, the only fixed watchkeeping position. Details of the itions selected are shown in Table E.2, and the results obtained in Tables and E.5.

nt In addition to these arrangements, a quartz fibre Dosimeter was pended in the Engineer's Workshop (the compartment immediately forward 'B' Boiler's economiser) to observe and compare, if possible, any transit e in this position with the corresponding doses in the boiler room. s meter was not, of course, monitored during fall-out, but was observed ediately afterwards. Unfortunately, like the others, no dose was recorded.

As reported in Section 4.2, the results recorded are so low as to ld no really useful information, apart from some confirmation of the rs. ults of the after-trial surveys (Section 4.3) and a very indefinite ication of deck shielding (Section 9.3). They are on occasions notice- e erratic. This can be attributed partly to inexperience of the operators, tly to the difficult conditions under which they were observed, and tly (particularly in 'B' Boiler Room, where the Survey Meter No. 3, est range 0-30 mR/Hr, was in use) to the smallness of the readings ative to the sensitivity of the instruments.

/ TABLE E.1

TABLE E.1 Boiler Room Monitoring Positions

a) Ratemeter monitoring positions:-

1. 1 ft. from centre of superheater furnace front.
2. 1 ft. from centre of saturated furnace front.
3. Control position, 4 ft. 6 ins. above plates.
4. T/A watchkeeper's position, 4 ft. 6 ins. above plates.
5. 3 ft. aft of centre of Economiser end door.
6. 3 ft. from Port blower room door.

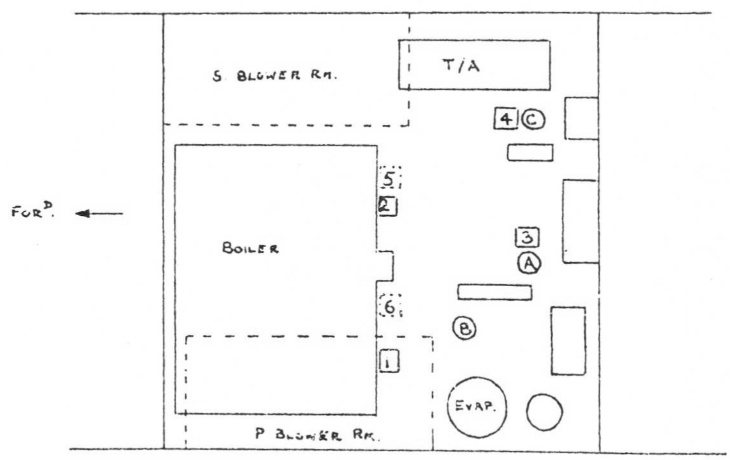
Note: Position 6 could not be reached in an air-ventilated suit, but it was considered that Position 1 would give warning of any dangerous build-up in the blower room. (The starboard blower room, being more shielded by the canvas curtain at the passage end - para. 3.1.2 (f) - was unlikely to be so heavily contaminated as the Port.)

b) Quartz Fibre Dosimeter Positions:-

A. P.O.'s Control Position, 4 ft. above plates.
B. Evaporator watchkeeper's position, 4 ft. above plates.
C. T/A " " " " "

c) Plan of Boiler Room, showing positions:- (Not to scale)

- Dotted lines indicate upper platform level -



☐ :- Ratemeter monitoring positions.

○ :- Quartz fibre Dosimeter positions.

/TABLE E.2

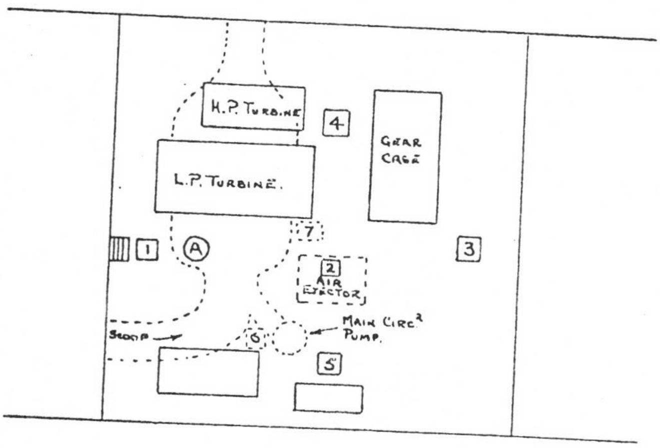
E.2 Engine Room Monitoring Positions

a) **Ratemeter monitoring positions:-**

1. At foot of access ladder, 3 ft. above Starting Platform.
2. Above Air Ejector, " " " " " level.
3. Aft end of centre gangway, " " " " " "
4. Above gearcase, 7 ft. from side, 3 ft. above Starting Platform level.
5. Inboard of M/G, 5 ft. from side, 3 ft. above Starting Platform level.
6. Between Scoop tube and Main Circ. Pp., 2 ft. above lower grating level.
7. 2 ft. aft of condenser, adjacent feed controller, 3 ft. above lower grating level.

b) **Plan of Engine Room, showing positions:-** (Not to scale)

- Dotted lines indicate lower platform level -



☐ :- Ratemeter monitoring positions.

Ⓐ :- Quartz fibre Dosimeter positions.

/ TABLE E.3

TABLE E.3 Boiler Room records - 'FLASHLIGHT'

Time	Ratemeter reading, mR/Hr. at position					
	1	2	3	4	5	6
1345	0	0	0	0	0	-
1415	0	0	0	0	0	-
1445	0	0	0	0	0	-
1515	0	0	0	0	1	-
1545	0	0	0	0	1	1
1615	0	0	0	0	1	2
1645	0	0	0	0	1	2
1715	0	0	0	0	1	1
1745	0	0	0	0	1	1
1815	0	0	0	0	1	1
1845	0	0	0	0	1	1

TABLE E.4 Engine Room records - 'HOTSHOT'

Time	Ratemeter reading, mR/Hr. at position						
	1	2	3	4	5	6	7
	All readings zero until 1535						
1535	.1	.05	.05	0	.05	0	0
1605	.1	.05	.05	.05	.05	0	0
1645	.1	.05	.05	.05	.05	0	0
1715	.1	.05	.05	.05	.05	0	0
1745	.1	.05	.05	.05	.05	0	0
1815	.1	.05	.05	.05	.05	0	0
1845	.1	.05	.05	.05	.05	0	0
1915	.1	.05	.05	.05	.05	.05	0
1945	.3	.2	.2	.1	.2	.1	.1
2035	.4	.2	.2	.2	.4	.2	.1
2105	.5	.2	.2	.2	.4	.2	.2
2135	.4	.3	.2	.2	.4	.2	.2

/ TABLE E.5

TABLE E.5 Engine Room records - 'FLASHLIGHT'

Time	Ratemeter reading, mR/Hr. at position						
	1	2	3	4	5	6	7
1345	.05	.05	.05	.05	.05	.05	.05
1415	.1	.1	.1	.1			
1445	.1	.1	.1	.1	.1		
1515	.1	.1	.1	.1	.1	.1	.1
1545	.3	.4	.4	.1	.1	.1	.3
1615	.5	.4	.4	.1	.1	.3	.3
1645	.5	.3	.4	.1	.3	.1	.1
1715	.5	.3	.4	.1	.4	.1	.1
1745	1.0	.3	.4	.1	.3	.1	.1
1815	.3	.2	.4	.1	.2	.2	.1
1845	.3	.2	.4	.3	.2	.2	.1
1915	.3	.2	.4	.4	.2	.2	.1
1945	.3	.2	.3	.4	.3	.2	.1
2015	.3	.2	.3	.4	.3	.2	.1
2045	.4	.2	.3	.4	.3	.2	.1
2115	.4	.2	.3	.4	.3	.2	.1

APPENDIX F.

BOILER POWER DURING FALL-OUT

F.1 During the whole period of each trial, the number and type of F.F.O. sprayers in use, and the F.F.O. pressure, on each furnace was recorded every 30 minutes.

F.2 Converting the actual times recorded into times from start of fall-out, the F.F.O. records into rate of burning fuel, and thence into fraction of full boiler power (18,000 lbs. F.F.O./Hr.), and estimating on combustion with 25% excess air on an average post-war type of Admiralty Fuel, yields the following table:-

Time (from start of fall-out Hrs.	HOTSHOT			FLASHLIGHT		
	Consumption, Lbs.F.F.O/Hr	% F.P.	Air Rate c.f.m. (at intake 75°F)	Consumption Lbs.F.F.O/Hr	% F.P.	Air Rate c.f.m. (at intake 75°F)
0	4460	25	17100	3820	21	14600
½	4460	25	17100	3820	21	14600
1	4300	24	16400	3820	21	14600
1½	5200	29	19900	3820	21	14600
2	4760	26	18200	3820	21	14600
2½	4760	26	18200	3820	21	14600
3	4500	25	17200	4720	26	18100
3½	4320	24	16500	4720	26	18100
4	4420	25	16900	6530	36	25000
4½	4680	26	17900	7010	39	26800
5	4790	27	18300	7010	39	26800
5½	4790	27	18300	7010	39	26800
6	4790	27	18300	-		
6½	4790	27	18300	-		
7	4790	27	18300	-		
7½	4660	26	17800	-		
8	4590	26	17500	-		
8½	4590	26	17500	-		

F.3 While this table cannot be supposed to be exact, it is sufficient to indicate roughly the quantity of air inhaled by the boiler during any period.

F.4 If we assume that, as seems most probable on the evidence, that fall-out was experienced from 1325 to 1330 and from 1910 to 2100 in 'HOTSHOT', and from 1325 to 1530 in 'FLASHLIGHT', then by plotting and integrating, estimates of the total air inhaled by the boiler result as follows:-

Contaminated air inhaled - 'HOTSHOT' :- 34,900 ft^3.

" " " - 'FLASHLIGHT':- 30,400 ft^3.

APPENDIX G.

ANALYSIS OF BOILER TEST RESULTS

1 General

G.1.1 This Appendix shows only the detailed analysis of the test results from the boiler trial. Their significance, and the conclusions therefrom, are discussed in Section 6 of the report proper.

G.1.2 It is not possible, by analysis of results of this type, to arrive at more than a rough approximation to the contaminant content of the boiler, and its distribution in the air/gas path.

G.1.3 The only method available is to take the mean 'count' from samples in a limited area, multiply it by the area, and use the resulting figure for comparison with those derived from other parts of the boiler. This must be done with some caution, having regard to the "mean error" of the counts, and its influence on overall reliability, and the effect on the latter of the number of samples tested and their similarity or otherwise of result.

G.1.4 Wherever possible, selection of area limits has been made so as to give the greatest areas on which deposition could be expected to be reasonably uniform. In some cases, notably the blower rooms, this has not been possible, owing to the intensely patchy contamination observed; in these cases a series of small area approximations has been used.

G.1.5 Soot samples have not been assessed as such. They have been used, however, to give an indication of the relative contamination likely to be found on steel surfaces between furnace and uptake (where it was not practicable to site plates), and no allowance has been made for loose soot.

G.1.6 It is not, strictly, possible to compare directly the plate and brick samples, owing to the fact that the brick contamination was fixed in the brick, and the counts are therefore reduced by self absorption. The amount of this self-absorption is not known, but is likely to be of the order of a multiple of 10. This multiplier has therefore been used in assessing the relative total contamination figures.

G.1.7 Siting of all samples is shown in figures 2 to 10 inclusive. Test results are shown in Appendix C, with a brief description of the location of each sample.

.2 'HOTSHOT'

G.2.1 The evidence of the air samplers is quite clearly that, of the active material entering, no significant quantity emerged from the funnel. This is not entirely borne out by the tests on plates, as activity was observed on all plates to the funnel top, but if as is most probable from the evidence the active material was here carried by the soot, these two results are not irreconcilable, as the very small amount of soot carried into the gas sampler was mainly deposited in the short pipe leading to the filter. The amount of soot leaving the funnel would in normal circumstances be very small.

G.2.2 Table G.1 shows the detailed analysis of the sample test results. In this statement there is no attempt to take account of the relative significance of the figures shown.

/ G.2.3

G.2.3 Table G.3 shows the summation of those figures from Table G.1 which may be considered significant, arranged as percentages of the total deposit to be found in the various major sections of the air/gas path. In this table also are corresponding figures from 'FLASHLIGHT'. (See below).

G.3 'FLASHLIGHT'

G.3.1 As in 'HOTSHOT', the evidence of the air and gas samples is that no significant proportion of the contamination emerged from the funnel. The evidence concerning carriage by soot is the same. The partial failure of the intake sampler, due to a pump diaphragm fault during the operation, in no way affects this evidence, though it unfortunately prevents any direct comparison in this way of the total contamination received during the two events.

G.3.2 Table G.2 shows the detailed analysis of the sample test results. The subdivision of areas is rather more detailed than that employed for the 'HOTSHOT' results, as there were available a considerably greater number of samples.

G.3.3 Table G.3 shows the summation of the significant figures from Table G.2 (and also Table G.1) arranged so that the results from 'FLASHLIGHT' and 'HOTSHOT' may be compared.

G.4 Comparison of Results

G.4.1 From comparison of the analysis results, as shown in Table G.3, it is at once obvious that the positions of the main deposits of contamination are, as was expected, the intakes and blower rooms, the furnace brickwork, and the sooty tubes.

G.4.2 It is therefore particularly unfortunate that operational requirements prevented the removal of the samples from 'FLASHLIGHT' until after sootblowing, and the projected tests on the effect of sootblowing after both operations.

G.4.3 Since therefore the true results are not strictly comparable, an attempt has been made to assess very roughly the effect of soot-blowing by adjusting as far as possible the soot sample counts to a comparable time datum, and also for the apparent overall level of contamination in each operation. The tube nest deposit figures for 'FLASHLIGHT' were then modified as indicated by this assessment, and the resulting adjusted deposit figures for the whole boiler are shown in Table G.3 alongside the true results. These "adjusted" results should be used with caution, as a large number of affecting factors are unaccounted for. It must also be borne in mind that the boiler was cleaned externally shortly before 'FLASHLIGHT'.

/ TABLE G.1

TABLE G.1.

ANALYSIS OF TEST RESULTS - 'HOTSHOT'

SECTION, and position	Sample Nos.	Mean Count	Area ft^2	"Activity Figure"	Total for Section (Integers)
PORT INTAKE					
Vertical Surfaces	87	3878	214	830	
Horizontal Surfaces(Top)	86	1591	30	48	
" " (Bottom)	88	61100	76	4640	5518
STBD. INTAKE					
Vertical Surfaces	74,75	25	214	5	
Horizontal Surfaces(Top)	73	8	30	0.2	
" " (Bottom)	76,77	7750	76	589	594
PORT BLOWER ROOM					
Outboard bulkhead, ½ deck, deckhead	94	23	301	6.9	
For'd. bulkhead	91	86	49	4.2	
Inboard deck, Aft and inboard bulkheads	93	52	181	9.4	
For'd blower and pipework	89	873	93	81.2	
Aft blower and pipework	92	131	100	13.1	115
STBD. BLOWER ROOM					
Outboard bulkhead, ½ deck deckhead	83,84	21	301	6.3	
For'd. bulkhead	81	625	49	30.6	
Inboard deck, Aft and inboard bulkheads	72,85	20	181	3.6	
For'd. blower and pipework	79	379	93	35.2	
Aft blower and pipework	80	17	100	1.7	77
BOILER CASINGS					
Blower discharge Trunking	15	31	448	13.9	
Back Casings	15,20,21	74	604	44.7	
Side Casings	20,31	15	671	10.1	
Economiser Casings	15	31	411	12.8	
Bottom Casings	21,29	110	464	51.0	
Front Casings	29,31,32	40	579	23.2	156
FURNACE BRICKWORK					
Adjusted for sample size and absorption	Bricks 1-6	1446	540	782	782
TUBE NESTS (From samples above economiser, adjusted for soot activity)	$62 \times \frac{243}{200}$	439	16135	7080	7080
UPTAKE AND FUNNEL					
Uptake below gas sampler	62	361	218	79	
Funnel above gas sampler	63	235	565	133	212
TOTAL - for Percentages:-					14534

Note: The "Activity Figure" listed is the product of the mean count per sample and the section area in square feet, divided by 10^3.

/ TABLE G.2

TABLE G.2.

ANALYSIS OF TEST RESULTS - "FLASHLIGHT"

SECTION, and Position	Sample Nos.	Mean Count	Area ft^2.	"Activity Figure"	Total fo Section (Integer
PORT INTAKE					
Vertical Surfaces	174,178	13762	214	2940	
Horizontal Surfaces(Top)	181	21	30	0.6	
" " (Bottom)	175,176,177, 179,180	8537	75	649	3590
STBD. INTAKE					
Vertical Surfaces	184	728	214	156	
Horizontal Surfaces(Top)	Pro Rata from Port		30	0.01	
" " (Bottom)	182,183	92	76	7	163
PORT BLOWER ROOM					
Outboard bulkhead, ½ deck deckhead	153,159, 164,170	22	301	6.6	
Forward bulkhead	172	14	49	0.7	
Aft bulkhead	151,152	0	49	-	
Inboard Forward ¼ of deck	169,173	237	32	7.6	
Inboard bulkhead and aft ¼ of deck	160	26	100	2.6	
For'd. blower body (external)	168,171	1858	28	52	
For'd. blower turbine	165,167	33	10	0.3	
For'd. blower pipework (lagged)	B,C	8853	55	487	
Aft blower body (external)	157,158	24	35	0.8	
" " turbine	161,165				
" " pipework (lagged)	154,155	0	10	--	
	A,D	47	55	2.6	560
STBD. BLOWER ROOM					
Outboard Bulkhead, ½ deck, deckhead	191,193	28	301	8.4	
Forward Bulkhead	190	27	49	1.3	
Aft Bulkhead	Pro Rata from Port		49	-	
Inboard For'd. ¼ of deck	187,188	353	32	11.3	
Inboard bulkhead and aft ¼ of deck	197	46	100	4.6	
For'd. blower body (external)	186,189	35	28	1.0	
For'd. blower turbine	185,192	347	10	3.5	
" " pipework (lagged)	Pro Rata from Port		55	722	
Aft blower body (external)	194,195, 196,199	29	35	1.0	
Aft blower turbine	198,200	29	10	0.1	
" " pipework (lagged)	Pro Rata from Port		55	3.8	757

/ TABLE G.

SECTION, and Position	Sample Nos.	Mean Count	Area ft^2.	"Activity Figure"	Total for Section (Integers)
LOWER DISCHARGE TRUNKING					
Port	11,12,13	105	224	23.6	
Starboard	49,50,51	23	224	5.2	29
ACK CASINGS, PORT					
Upper Third	11,12,13	105	101	10.6	
Middle Third	14,115, 16,17	11	101	1.1	
Lower Third	18,19,120, 121,22	23	101	2.3	14
ACK CASINGS, STARBOARD					
Upper Third	47,48,49 50,51,52.	15	101	1.5	
Middle Third	46,53,54	15	101	1.5	
Lower Third	43,44,45	30	101	3.0	6
CONOMISER CASING	49,50,51	23	411	9.5	10
IDE CASINGS	1-10 Incl.	17	671	11.4	11
OTTOM CASINGS					
Port (below superheater furnace)	23,24,25, 26,27,28	15	232	3.5	
Stbd. (below saturated furnace)	36,37,38, 39,40,41, 42	39	232	9.1	13
RONT CASINGS					
Port (Superheater furnace)	129,30,131	39	232	9.1	
Stbd.(Saturated furnace)	132,33,34, 35	60	347	20.8	30
URNACE BRICKWORK (Allowing for sample size and absorption)	Bricks 1-10	4084	540	2200	2200
UBE NESTS (From plates above economiser, adjusted for soot activity)	55-61 incl. 162, x 60/32.	120	16135	1936	1936
PTAKE					
Below Gas Sampler	55,56,57, 58,59,60, 61,162	60	218	13.3	13
UNNEL					
Above Gas Sampler	65,66,67, 68,69,70, 71	57	565	32.2	32
OTAL - for Percentages:-					9364

/ TABLE G.3

TABLE G.3.

BOILER TRIAL

SUMMARIZED RESULTS COMPARED

POSITION IN SYSTEM	DEPOSIT, % OF TOTAL IN BOILER		
	HOTSHOT	FLASHLIGHT	
	(Before Sootblowing)	(After Sootblowing)	(Before Sootblowing) - "adjusted" estimat[e]
INTAKES -			
Port	38	39	
Starboard	4	2	
- TOTAL	42	41	34
BLOWER ROOMS -			
Port	0.5	6	
Starboard	0.8	8	
- TOTAL	1	14	11
BOILER CASINGS	1	1	1
FURNACE BRICKWORK	6	23	19
TUBE NESTS	48	20	33
UPTAKE AND FUNNEL	2	1	2
	100	100	100

APPENDIX H.

EXTRACTS FROM "HEALTH PHYSICS REGULATIONS
H.M.S. DIANA - OPERATION MOSAIC".

.1. The following extracts from Section 2 - "Maximum Permissible Levels" - f the Health Physics Regulations for H.M.S. DIANA are reproduced here in rder to show the levels of contamination accepted as safe from the point of iew of the "Internal Hazard". The appropriate paragraph showing the llowable doses of external radiation has also been included, to complete he picture.

.2. The instructions for washing referred to in 2.3.1 of the regulations, id given in full later in the same document, require at least three changes f washing water in addition to clean water for rinsing. It is therefore lear that in the event of any widespread contamination of personnel, the rain on water supply might easily be beyond a ship's capacity.

.3. It is noteworthy that the tolerances for loose contamination, which are quivalent to a 'count' of 4 in 100 seconds for Beta/gamma contamination, ested with the equipment used in these trials, require a very long test of ach smear, at least 20 minutes, if a reliably significant result is to be btained with background "counts" of the order of 50 to 70 per 100 seconds. ests for alpha contamination require at least 5 hours for the same relia- ility. Tests of these lengths are quite impracticable in the circumstances f this operation.

.4. It is therefore legitimate to conclude that either the tolerances or the quipment require modification, to relate the one more realistically to the ther, in any future operations of this nature.

.5. Very much the same may be said of the drinking water tolerances, which re even less related to the test equipment available. This situation is ferred to in more detail in section 8 of the report proper.

"2.1. External Radiation.

"2.1.1. Total Integrated Dose - not to exceed 15 rep per event with a gamma component of 3R. In any special case authorised by the M.O., H.M.S. DIANA and the Team Leader, Scientific Party, to recover records which might otherwise be lost, a dose of 50 rep with a maximum gamma component of 10R may be received. In case of extreme necessity a dose of 75 rep with a gamma component of 25R may be authorised. Authoris- ation is needed by the M.O., H.M.S. DIANA, Team Leader, Scientific Party, and C.S.S.

"2.2. Internal Radiations.

"2.2.1. The maximum permissible levels will be:-

(i) In water, 10^{-7} $\mu c/cc$.

(ii) In air, (a) for α emitters 2×10^{-12} $\mu c/cc$.

(b) for β/γ emitters $\frac{10^{-6}}{T}$ $\mu c/cc$,

where $0.25 \leq T \leq 5040$, and T is the time in hours after the explosion.

"2.3. Contamination Levels.

"2.3.1. Except in the case of the hands and body, contamination can be regarded as fixed when a smear test gives a value below the maximum permissible levels. In the case of the hands and body it is defined as that which remains after washing in accordance with the instructions.

"2.3.2. The maximum levels of fixed surface contamination will be:-

Alpha. 600 disintegrations/min. on both sides of one hand
20 dpm/cm^2 - clothing, equipment, etc.

60 dpm/cm^2 - decks.

Beta/Gamma. 6000 dpm on both sides of one hand.
400 dpm/cm^2 - clothing, equipment.

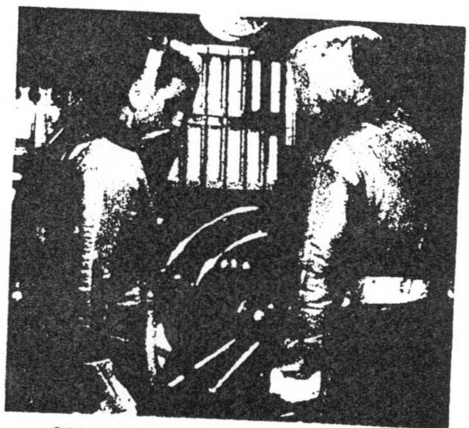
1200 dpm/cm^2 - decks.

"2.3.3. The maximum permissible levels of loose contamination will be:.

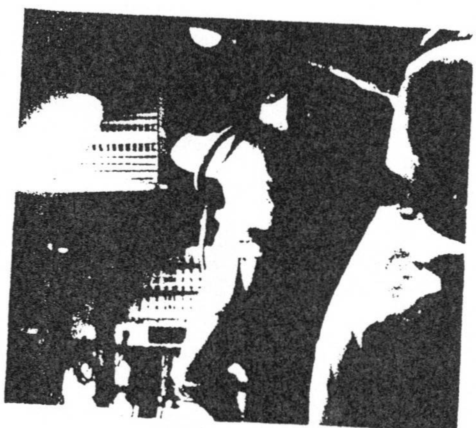
Alpha - 5 dpm per smear.
Beta/Gamma - 20 dpm per smear. "

AIR-VENTILATED PROTECTIVE SUITS.

ENTERING SPACE, USING HAND-BELLOWS FOR AIR SUPPLY.



COMPLETE ENGINE-ROOM WATCH



THIS WAY OUT

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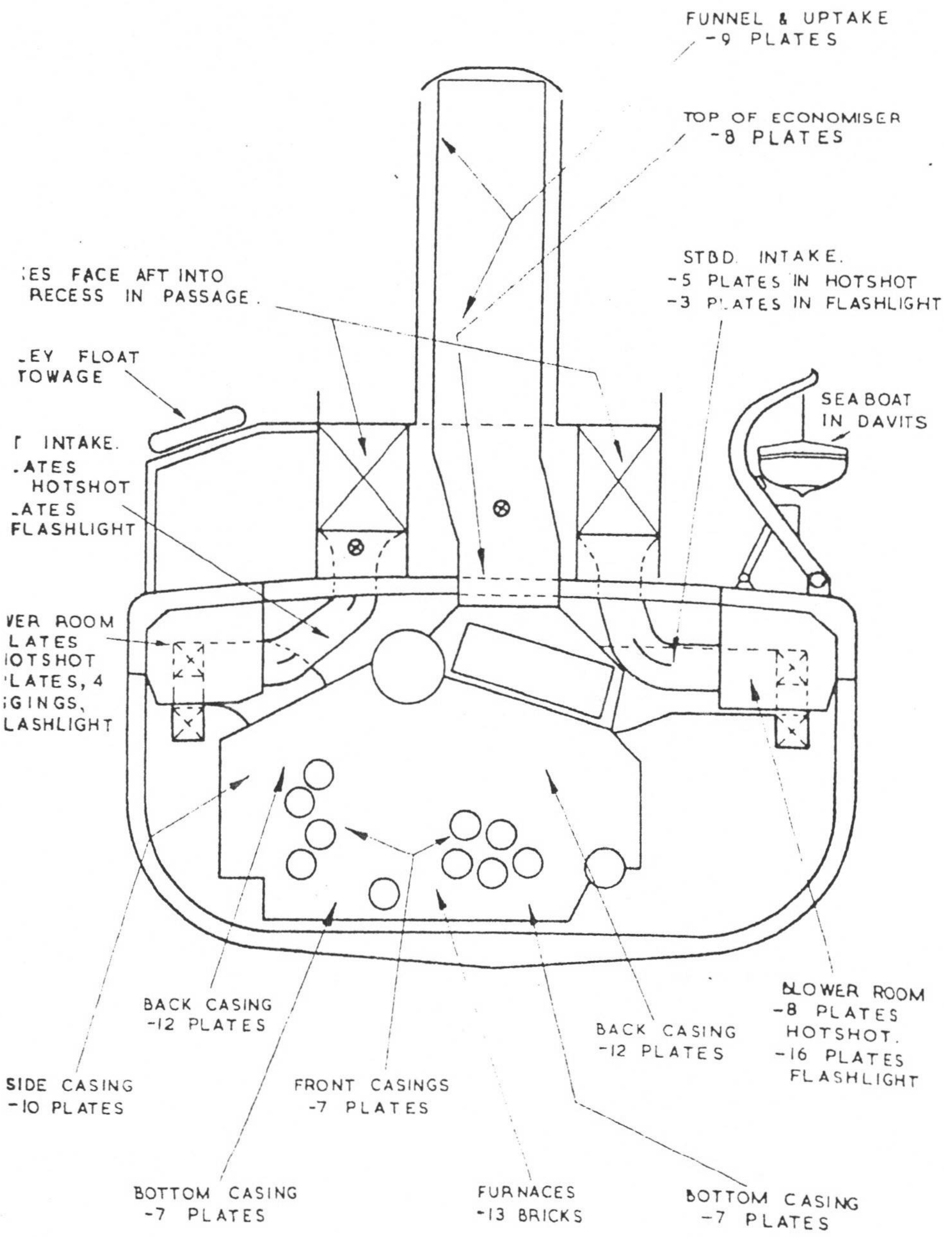


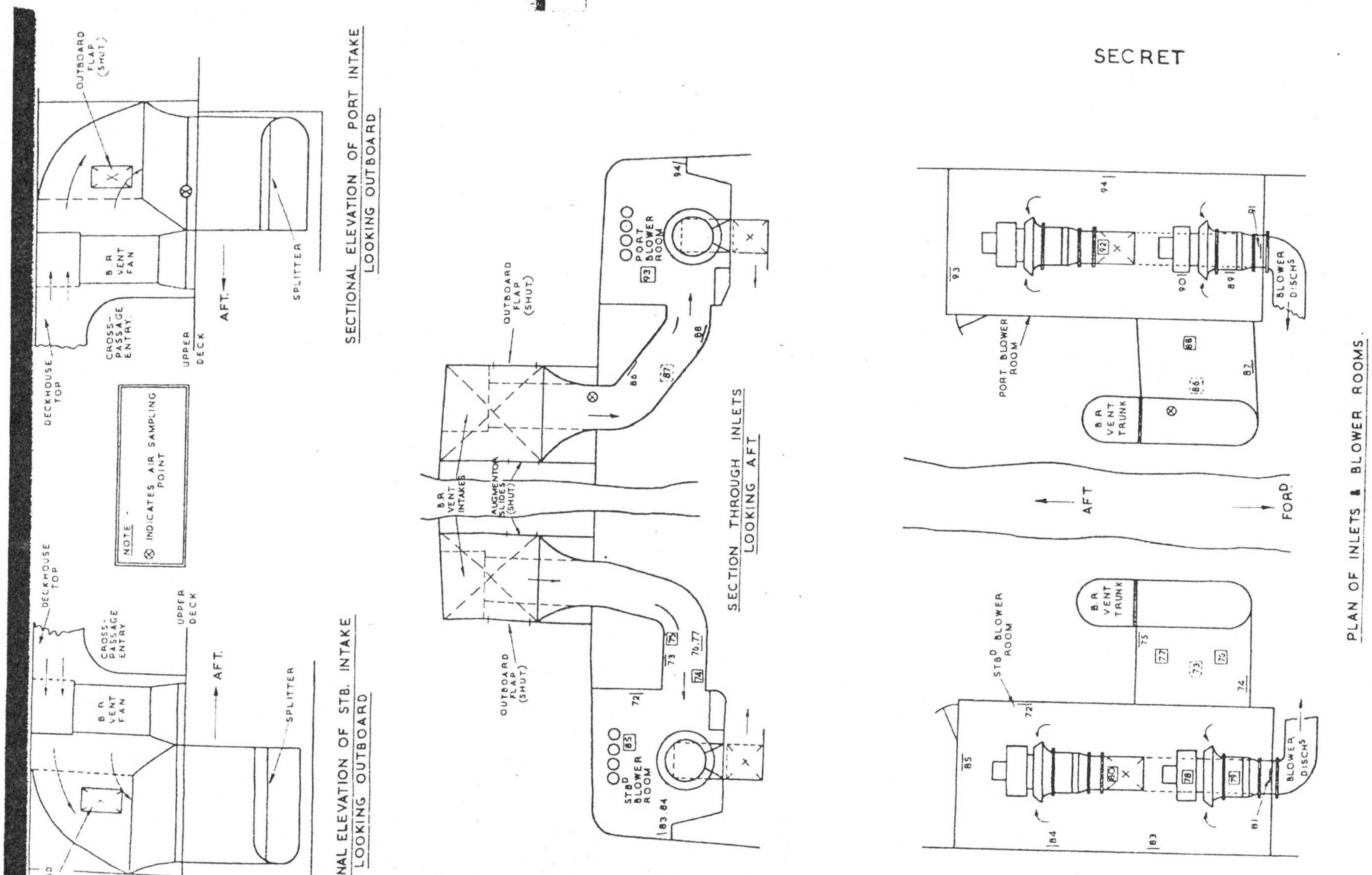
GENERAL ARRANGEMENT OF BOILER SAMPLES

- SECTION THROUGH 'B' BOILER ROOM LOOKING FORWARD. -

E-IN-C 4646 R

SECRET

FIG 2



ARRANGEMENT OF SAMPLES
IN BOILER INTAKES AND BLOWER ROOMS.
-HOTSHOT-

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FIG.3

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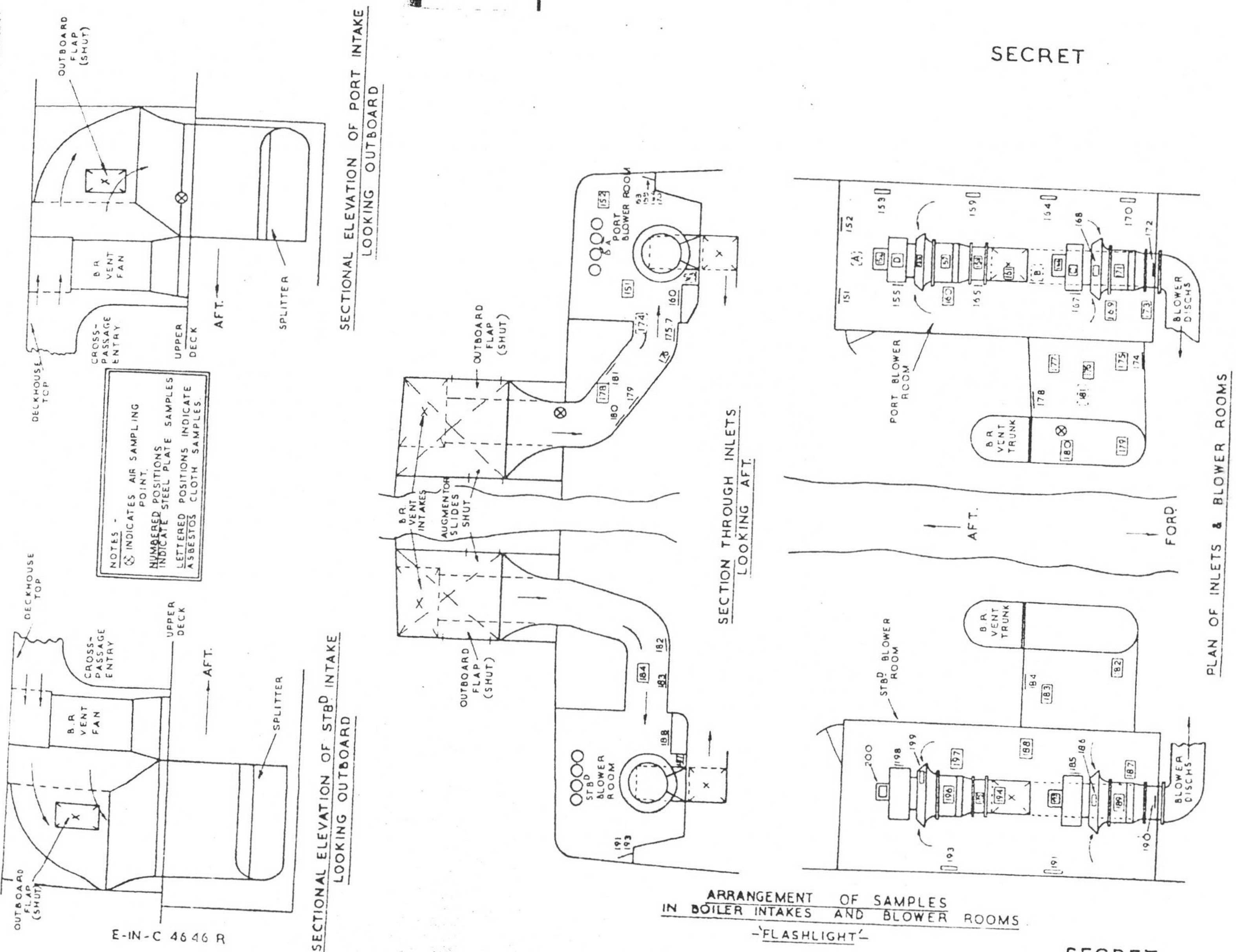
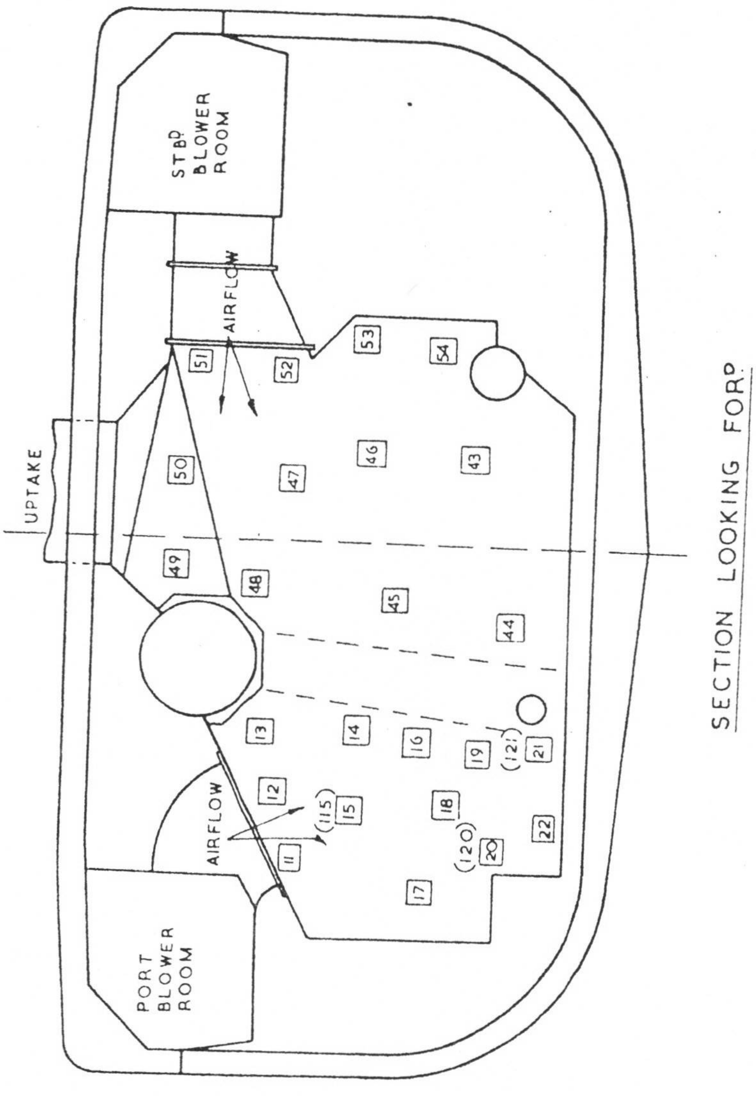


ARRANGEMENT OF SAMPLES IN BOILER INTAKES AND BLOWER ROOMS
-'FLASHLIGHT'-

SECRET

FIG

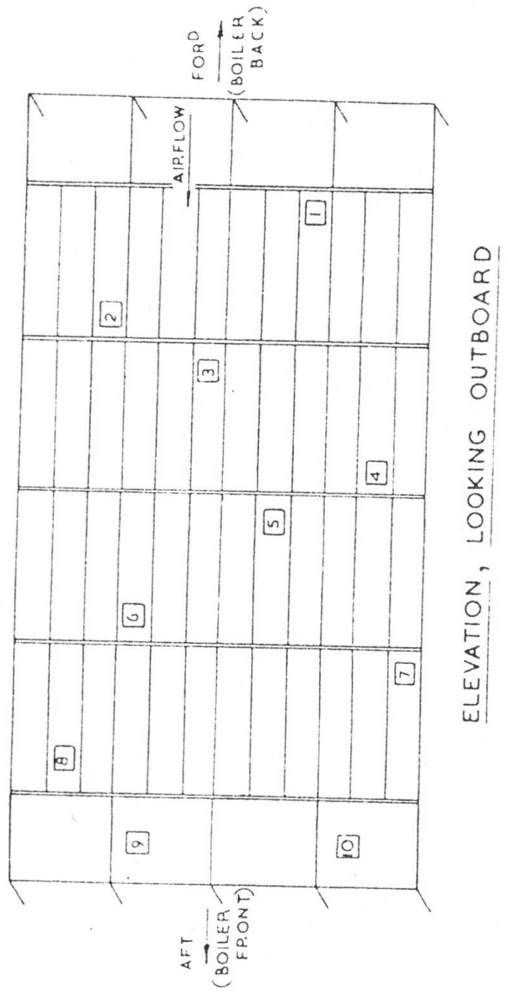


ARRANGEMENT OF PLATES IN BOILER CASINGS.

– BACK CASING –

NOTE – NUMBERS IN PARENTHESIS INDICATE PLATES FROM THE SERIES 101-200 USED TO REPLACE CORRESPONDINGLY NUMBERED PLATES IN THE SERIES 1-100 AFTER 'HOTSHOT.'

SECRET

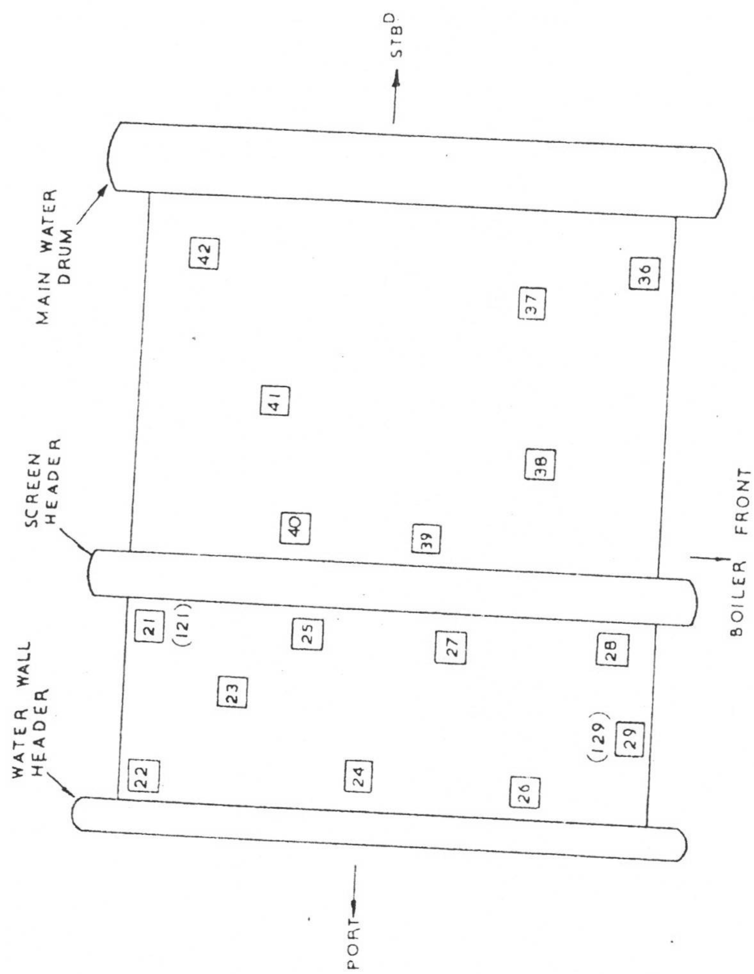


ARRANGEMENT OF PLATES
IN BOILER CASINGS.

– SIDE CASING –

E-IN-C 4646 R SECRET FIG. 6

SECRET

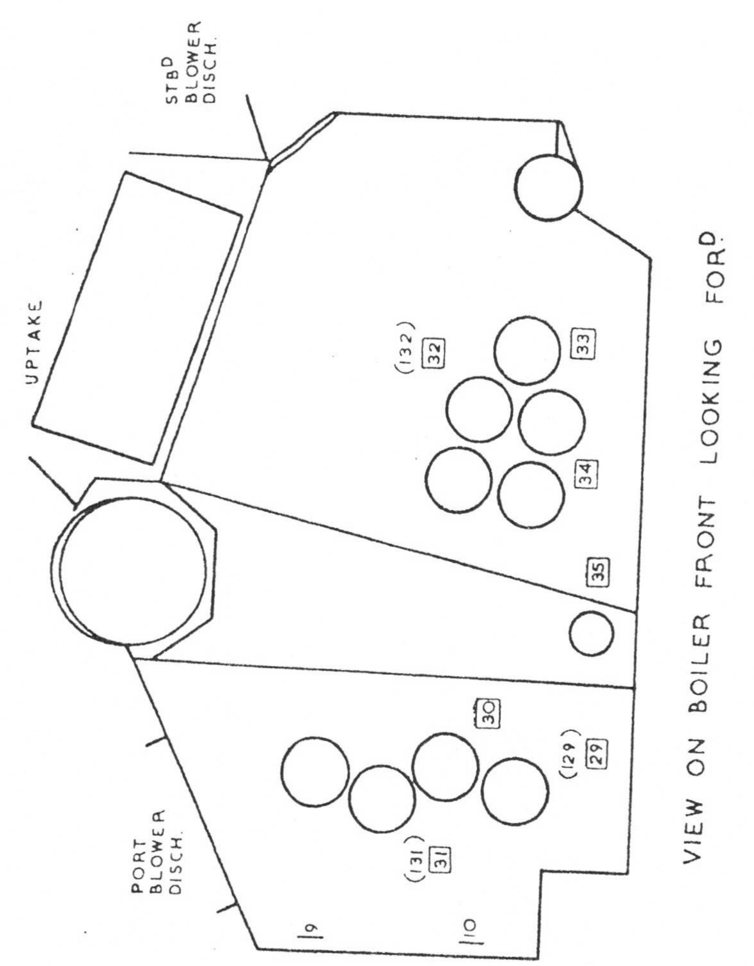


PLAN VIEW BELOW FURNACE

ARRANGEMENT OF PLATES
IN BOILER CASINGS.

–BOTTOM CASINGS–

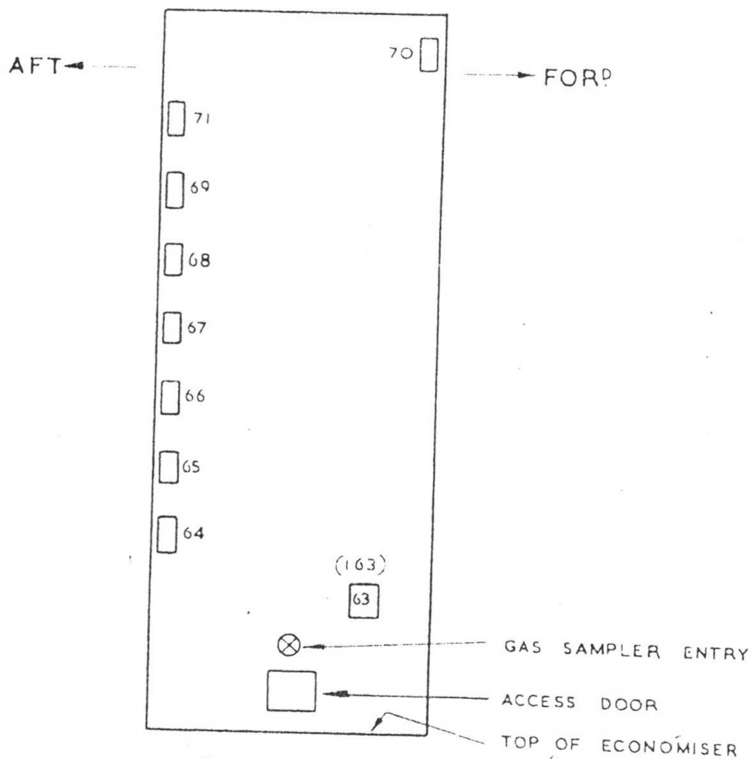
NOTE :- NUMBERS IN PARENTHESIS INDICATE PLATES FROM THE SERIES 101-200 USED TO REPLACE CORRESPONDINGLY NUMBERED PLATES FROM THE SERIES 1-100 AFTER 'HOTSHOT'



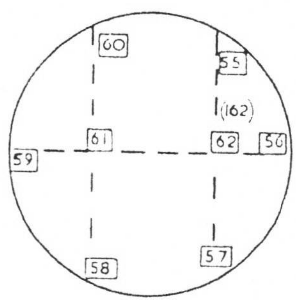
ARRANGEMENT OF PLATES IN BOILER CASINGS.

—FRONT CASINGS—

NUMBERS IN PARENTHESIS INDICATE PLATES FROM THE SERIES 101-200 USED TO REPLACE SIMILARLY NUMBERED PLATES IN THE SERIES 1-100 AFTER "HOTSHOT"



ELEVATION



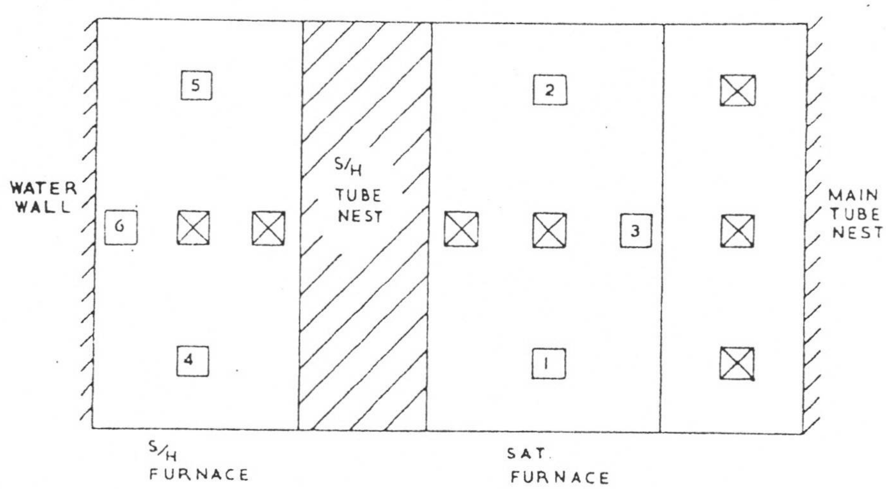
PLAN AT BASE OF UPTAKE

ARRANGEMENT OF PLATES
IN UPTAKE AND FUNNEL.

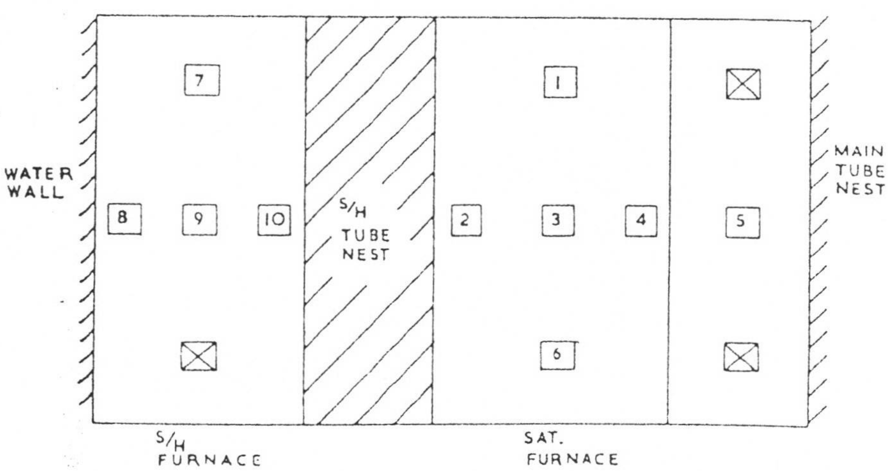
JMBERS IN PARENTHESES INDICATE PLATES REPLACED AFTER HOTSHOT.

SECRET

(a) - HOTSHOT



(b) - FLASHLIGHT

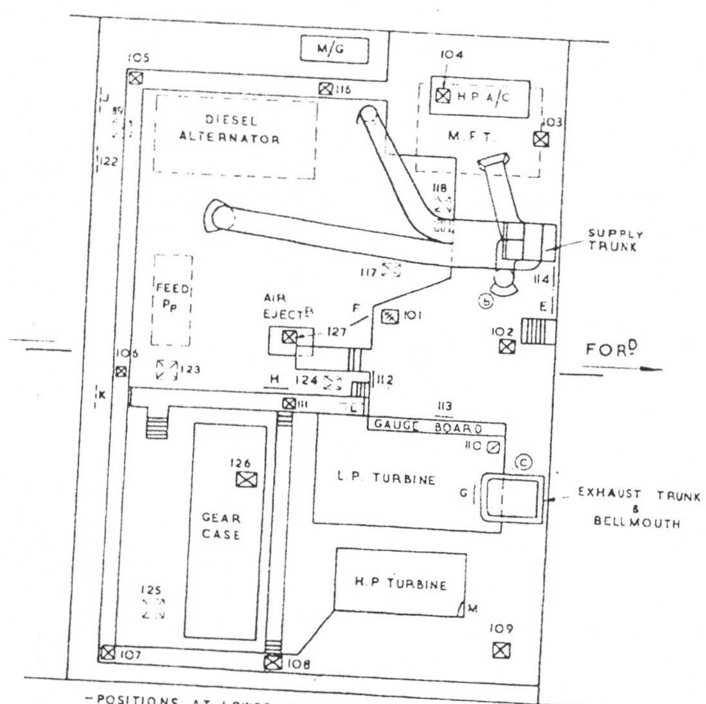


☒ :- SAMPLE NOT RECOVERABLE

ARRANGEMENT OF BRICK SAMPLES IN BOILER FURNACES.

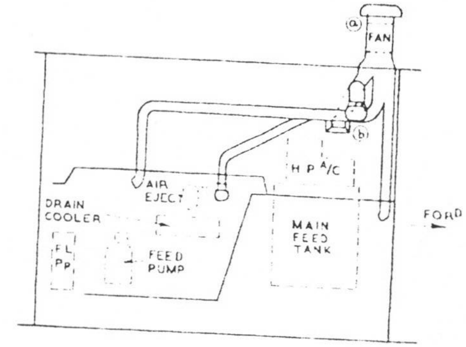
-PLAN-

E-IN-C 4646 R SECRET FIG. 10

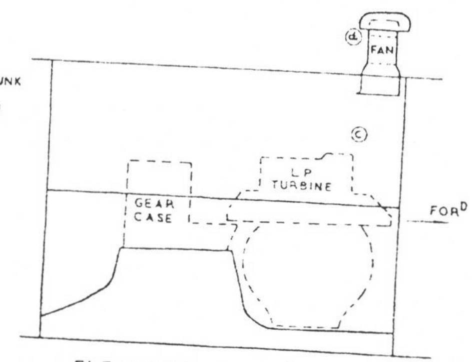


- POSITIONS AT LOWER PLATFORM LEVEL SHOWN DOTTED -

PLAN



ELEVATION AT ℄
- LOOKING TO PORT -
- SHOWS SUPPLY SYSTEM -

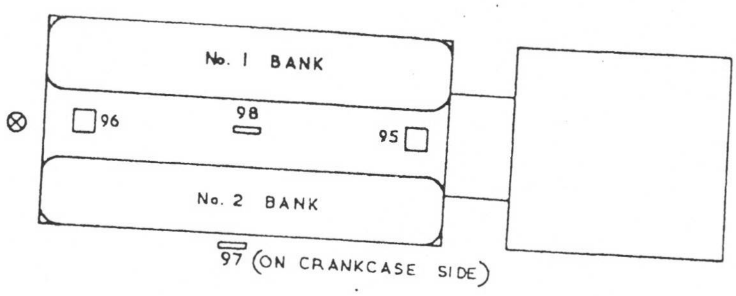


ELEVATION AT STBD SIDE
- LOOKING TO STBD -
- SHOWS EXHAUST SYSTEM -

ENGINE ROOM VENTILATION SYSTEM.
SHOWING SAMPLE POSITIONS.

NOTES - 1 VENTILATION SYSTEMS NOT USED DURING THESE TRIALS ARE OMITTED
2 (a) INDICATES AIR SAMPLING POINT. - REF: SECTION 7
3 NUMBERED POSITIONS INDICATE STEEL PLATE SAMPLES } SHOWN ON PLAN ONLY
4 LETTERED POSITIONS INDICATE LAGGING CLOTH SAMPLES }

E-IN-C 4646 R



ENGINE

ALTERNATOR

⊗ INDICATES AIR SAMPLING POINT

DIESEL ALTERNATOR

ARRANGEMENT OF PLATES AROUND CYLINDER HEADS.

– SAME PLATE Nos. FOR BOTH OPERATIONS –

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OPERATION MOSAIC

II

THE FALLOUT ANALYSED WITH REFERENCE TO H.M.S. DIANA.

BY

E.M.L. BEALE

MARCH 1957

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OPERATION MOSAIC.

II. THE FALLOUT ANALYSED WITH REFERENCE TO H.M.S. DIANA

By

E.M.L. Beale.

SUMMARY

After each of the atomic weapon tests that took place in the Montebello Islands in 1956, H.M.S. DIANA was stationed in the fallout area, to obtain scientific data on fallout and to provide operational experience of conditions that may arise in nuclear warfare.

On each occasion DIANA received just about the intended amount of fallout.

It is concluded that if a similar operation were planned in the future, the instructions concerning the stationing of the ship should be made more flexible, details being decided in the light of the actual upper wind structure. The intended amount of fallout could also be increased by a factor of 10 in favourable circumstances, but an increase by a factor of 100 does not seem justified.

SECRET DISCREET

1. INTRODUCTION

Two atomic devices, known as G1 and G2, were exploded on towers in the Montebello Islands on 16th May 1956 and 19th June 1956 respectively. It was arranged that H.M.S. DIANA should be stationed in the fallout area from each shot, to obtain scientific data on fallout and to provide operational experience of conditions that may arise in nuclear warfare.

It was planned that DIANA should be stationed so as to receive as much fallout as possible consistent with ensuring that no member of the ship's company received a biologically significant dose of radiation, allowing for uncertainty in the calculated intensity of fallout and for the possibility that the ship's prewetting system might fail. On both occasions DIANA received just about the intended amount of fallout; on both occasions this was achieved as a result of local initiative overruling one aspect of the Admiralty Instructions.

It was also planned that an unmanned whaler equipped with scientific instruments should be placed in the fallout area within a few miles of ground zero. This part of the plan was successful, except that the whaler for G2 was inadvertently sunk the day before, and had to be replaced by a Dan Buoy equipped with sticky tape and collector trays.

The Admiralty Instructions for the trial are discussed in the light of recent information of fallout in Section 2 of this report. An analysis of DIANA's experiences after the two shots is made in Sections 3 and 4. The fallout on the whaler and the Dan Buoy is discussed in Section 5. Some conclusions relevant to the planning of future operations of this kind are discussed in Section 6.

2. THE ADMIRALTY INSTRUCTIONS

The Admiralty Instructions for the operation are contained in Ref. 1, sent under cover of a letter, M/TSD62/56, from the Admiralty to the Commodore Special Squadron on 13th April, 1956. The essential features of these instructions were that DIANA should be stationed in a direction from ground zero so as to receive fallout from the bottom of the puff of the atomic cloud, and at such a distance that the estimated hypothetical peak total gamma dose in an infinite field would be 5 roentgens. The Theoretical Predictions group of the A.W.R.E. team at the trial, consisting of A.G. Matthewman and J.D. Macdougall, were responsible for predicting the fallout pattern from a radiological safety point of view, and they undertook to advise the Commodore where DIANA should go to comply with these instructions, using theories of the distribution of fallout derived at A.W.R.E. and A.R.L.

The radiation levels are discussed by D.W. Soole in Ref. 2 as follows:-

"Protection Afforded by the Ship

"The dose figures .... assume that the dose is received from an infinite plane source of contamination. In practice the largest area from which radiation could possibly be received is the horizontal weather deck of the ship, since material falling on the surface of the sea will sink sufficiently for its radiation to be completely cut off." [Radioactive material that has recently fallen on the sea will be concentrated in the top few feet, and can give measurable dose rates inside a ship, particularly below decks. But this material diffuses fairly rapidly and will not make a significant contribution to the total gamma dose received inside the ship, even if the ship remains in that part of the sea for a long time]. " Experiments at A.R.L. (J.H. Williams) have shown that whereas an infinite area uniformly contaminated with cobalt 60 (1 curie/sq. ft.) will produce a dose rate of 500r/hr. at a position 3 ft. 6 ins. above the deck, the same density of activity on the deck of the frigate RAPID will produce a dose rate of only [illegible]r/hr, i.e. a reduction of 48%.

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"The A.R.L. experiments also showed that at the least protected of the covered positions for which measurements were made in RAPID, namely the Captain's Position on the enclosed Bridge, the dose-rate was reduced to 40% of what it was on the weather deck. Thus the combined effect of a limited surface contamination by fall-out and the physical shielding of the ship will produce a protection factor of approximately $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$. A similar figure of $\frac{1}{4}$ will apply to the slightly less penetrating radiation received from the fall-out deposited on the weather deck of DIANA (which is comparable in area with that of RAPID).

"By adequate pre-wetting of the ship's exposed surface followed by effective washdown, indications are that approximately 75% of the fall-out can be washed away, i.e. a further protection factor of $\frac{1}{4}$ is effective.

"Thus, for personnel under cover, at sea, in a ship which is being adequately pre-wetted and washed down, protection factors of approximately $\frac{1}{4} \times \frac{1}{4} = 1/16$ are applicable.

"Stationing of H.M.S. DIANA

"From a consideration of the above protection factors and the radiation tolerance doses ....., it has been decided that DIANA shall be at that distance from ground zero at which the hypothetical peak total dose in an infinite field would be 5 roentgens. The following will then apply:-

Dose from an infinite field	5 r
Dose on deck	2.5 r
Dose below deck (no washdown)	≤1.25 r
Dose below deck (pre-wetting and washdown)	≤0.3 r

"It should be noted that the dose to personnel below deck in an adequately pre-wetted and washed down ship is equal to the weekly dose at the Normal Working Rate.

"It should also be noted that should by an unfortunate mischance, Beale's curves be as much as 20 times too low, AND the pre-wetting and washdown procedures be inoperative, then the dose received by personnel just below the weather deck will be 20 x 1.25r = 25r which is no more than the Special Higher Integrated Dose."

These levels of contamination were accepted by the A.R.L. experimental team before the event. It has subsequently been suggested that they were too low. However, even if the requirement for higher levels of contamination had been foreseen, it could not safely have been met unless it was agreed that the safety factor of 20 mentioned above was unduly conservative. Recent U.S. information on fallout suggests that this was a very reasonable safety factor considering the extent of our knowledge of the distribution of fallout at the time. If one uses the present (post-shot) estimates of yield, one finds that the densities of fall-out at the time of arrival on DIANA (about H+8 hours for G1 and about H+4 for G2) estimated from the formulae used at the time agree to within a factor of 2 with those given by the latest U.S. cloud model, though the U.S. Cloud Model gives about 4 times as much material deposited between H+1 and H+4 hours from G1. However, the U.S. representatives at the conference reported in ref. 3 stated that "errors of a factor of 10 in estimates of peak dose rate at a given distance [illegible] forecast winds and yields." ~~In this connection it should be noted that, for both G1 and G2, the best estimate of yield available immediately after the event was substantially higher than the value now accepted.~~

The decision that DIANA should be stationed so as to receive fallout from the bottom of the main cloud, rather than from near the centre of the main cloud, has also been criticised. At the time, no precise information concerning the height of origin of the fallout was available. It was felt that if DIANA

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"By adequate pre-wetting of the ship's exposed surface followed by effective washdown, indications are that approximately 75% of the fall-out can be washed away, i.e. a further protection factor of $\frac{1}{4}$ is effective.

"Thus, for personnel under cover, at sea, in a ship which is being adequately pre-wetted and washed down, protection factors of approximately $\frac{1}{4} \times \frac{1}{4} = 1/16$ are applicable.

"<u>Stationing of H.M.S. DIANA</u>

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"It should be noted that the dose to personnel below deck in an adequately pre-wetted and washed down ship is equal to the weekly dose at the Normal Working Rate.

"It should also be noted that should by an unfortunate mischance, R ale's curves be as much as 20 times too low, AND the pre-wetting and washdown procedures be inoperative, then the dose received by personnel just below the weather deck will be 20 x 1.25r = 25r which is no more than the Special Higher Integrated Dose."

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"In this conn[redacted]
G2 the estim[redacted] te
were substantially higher than the value achieved".

The decision that DIANA should be stationed so as to receive fallout from the bottom of the main cloud, rather than from near the centre of the main cloud, has also been criticized. At the time, no precise information concerning the height of origin of the fallout was available. It was felt that if DIANA

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was stationed to receive fallout from the middle of the cloud then errors in estimating the wind field might cause her to miss the fallout altogether, but that if she was stationed to receive fallout from the bottom of the cloud then she would certainly receive something, either from the main cloud or from the stem. In fact the latest U.S. cloud model given in Ref. 3 suggests that the distribution of heights of origin of contamination falling at a given time is nearly symmetrical except at very early times. Therefore if the wind structure is fairly "normal" i.e. if the mean wind speed to all relevant heights is approximately constant and the mean wind direction is an approximately linear function of height, then it would be desirable to station any ship hoping to receive fallout so as to receive it from near the mean height of origin of fallout arriving at the time selected. This mean height depends on the time divided by the height of the top of the cloud. It is shown in Fig. 1 for clouds with tops at 24 and 48 thousand feet, these being the approximate heights of the G1 and G2 clouds respectively. It will be seen that the mean height of origin is below the centre of the puff except at very late times of arrival, but that it is above the bottom of the puff for all times after the first hour or so. Although the cloud model gives as much as 15.7% of the total fallout originating from the top half of the stem, most of this material is depo...

In fact the instruction that DIANA should try to receive fallout from the bottom of the cloud would have worked out very badly on both Mosaic shots, if DIANA had obeyed it. At G1 the mean wind speed to the bottom of the cloud was about 6 knots, so fallout would not have reached DIANA at the recommended distance of 60 miles until about H+10 hours. The U.S. Cloud Model suggests that very little material from the top of the stem or the bottom of the cloud arrives at such late times, so it was a good thing that DIANA did not wait for it but moved off and intercepted the fallout from near the middle of the lower half of the puff at about H+8 hours, where it received just about the intended amount of contamination. After G1, D.M.C. Thomas (A.R.L.) and A.G. Matthewman (A.W.R.E.) decided that for G2 DIANA should be stationed so as to receive fallout from 1000 feet below the centre of the puff. This was a fortunate decision, since the direction of the mean wind to the bottom of the puff (about 24 thousand feet) changed radically in the 8 hours following the explosion, and DIANA would have missed the fallout altogether if she had been stationed at the recommended distance of 120 miles in the direction indicated by the shot time winds as suitable for receiving fallout from this height.

3. ANALYSIS OF DIANA'S MOVEMENTS - G1.

A past-shot fallout analysis for G1 is shown in Fig. 2. The top of the atomic cloud stabilized at about 24 thousand feet. The points where fallout should have arrived from heights of 4, 8, 12, 16, 20 and 24 thousand feet at times 4, 8 and 12 hours were computed from the wind field as observed over the Montebello Islands, Onslow and Port Hedland. (The falling velocity of each particle was assumed to vary as $e^{-0.01z}$, where z represents height in thousands of feet, this form of variation of falling velocity with height throughout the troposphere being suggested by Refs. 4 and 5.) These points are plotted in Fig. 2, where broken lines have been drawn representing "centre lines" of fallout arriving at a given time (i.e. H+4, H+8 and H+12 hours) and dotted lines have been drawn representing "centre lines" of fallout arriving from a given height.

The mean density of fallout, measured in 1-hour curies per square metre, computed from the U.S. cloud model of Ref. 3 assuming a radiological yield of 1 KT is shown for each of the cells formed by the two systems of centre lines. The radiological yield is defined as the radiochemical yield multiplied by the fraction of the fission products falling within the first 24 hours or so. It may be assumed that the radiological yield of G1 was somewhat greater than 1 KT.

The track of H.M.S. DIANA, as reported in Appendix A to Section 1 of Ref. 6, is plotted as a continuous line in Fig. 2, the times being translated into hours and minutes after shot time. The narrative in Section 1 of Ref. 6 can now

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be studied in the light of the information given in Fig. 2. The times are referred to H hour as in Fig. 2.

"A ... position ...002°40 miles from Ground Zero was ordered by C.T.F.308 ...

"At H Hour, 1200 "[actually H+9 minutes]" I was three miles east of this position and course and speed were adjusted so as to pass through it at H+1.34, the E.T.A. of the fall out, and steering [illegible] at 10 knots. This gave a relative wind speed of 13 to 15 knots.

"Fall out arrived as expected but stopped after twenty minutes. This fact, together with the observed path of the cloud after H hour, was interpreted as meaning that I had only cut across a small sector of the leading edge of fall out, and that the main area lay to the E.[illegible].E."

Post shot analysis suggests that the fallout should not have arrived at this point for another 7 hours. The observed fallout, which was recorded on three separate instruments and was therefore undoubtedly present, was one of the freak patches of low but measurable radioactivity that are known to arise after atomic explosions.

In the presence of substantial angular wind shear the [illegible] of the main cloud is not much of a guide to the direction in which [illegible] fallout arrives. However at G1 it did correctly indicate that the upper winds were blowing from the West, so that the fallout from the upper part of the cloud should be arriving to the East of the fallout from the lower part of the cloud. The decision to move East was entirely reasonable in the circumstances.

"I therefore altered course to 070 at H+1.[illegible], informing C.T.F.308 of my actions. At H+2.48 course was altered to [illegible] and [illegible] increased to 15 knots, to comply with [illegible] from C.T.F.308" "[These further instructions were based on the [illegible] of yield, and on the estimated mean wind direction [illegible] estimate of the cloud, rather than the predicted [illegible] of the cloud.]" The new position ordered was reached at H+4.2[illegible] but without [illegible] any fall out, so course was altered to 100° at H+4.3[illegible] and [illegible]° at H+[illegible].12. This was reported to C.T.F.308 who then ordered me to steer 090°."

The lack of fallout in this region at this time is not surprising since fallout should not have arrived for another 5 hours or more. However the decision to move East immediately was a sound one, since present information suggests that very little activity falls from the top of the stem at these late times. Had the ship waited, the activity would probably have been down by a factor of 20 or so on what was actually obtained. The A.W.R.E. Theoretical Predictions Group were aware that the Admiralty Instructions were drafted with a much higher mean wind speed and smaller angular wind shear in mind. While reluctant to take the initiative in disobeying the Admiralty Instructions, they were [illegible] very willing to co-operate with DIANA in seeking fallout from nearer the centre of the cloud.

"A small patch of active water was found at H+[illegible] and at H+7.19 more considerable activity in the water was discovered. It had stopped by H+7.44 and so course was reversed to 270°.

"However no greater activity was detected and at H+8.14 I altered course to 214°, the bearing of Ground Zero. At this stage, H+8 hours, it was felt that no further value was to be gained by searching.

"Fall out ceased at H+9.09."

The more active patch of water was encountered at about H+7½ hours, and Fig. 2 suggests that DIANA did indeed cross the H+7½ hour centre line.

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However she did not catch up with fall out again after altering course to 070°, though she could have done so if she had altered course to 000°. It is therefore not surprising that no greater activity was detected after this alteration of course.

The U.S. Cloud Model suggests that H.M.S. DIANA should have received a density of contamination of about 10 1-hour millicuries per square metre of horizontal area for each KT radiological yield. This corresponds to about $10(12)^{-1.2} \approx 0.5$ mc/m². KT radiological yield at H+12 hours. On a flat infinite plane 0.5 mc/m² would give a gamma dose rate of about 5 mr/hr at a height of 3 feet. According to the passage from Ref. 2 quoted in Section 2 above, this corresponds to a dose rate of about 2.5 mr/hr on the upper deck of an unprewetted ship, or about 0.6 mr/hr on the upper deck of a prewetted ship.

According to Ref. 6, the observed dose-rates on the upper deck were of the order of 5 mr/hr at H+12 hours. Since the bulk of the activity arrived at about H+7½ hours, this corresponds to a total dose to infinity of about 0.3r on the upper deck of the prewetted ship. This compares very adequately with the calculated densities of contamination, and with the target dose of 0.6r on the Upper Deck of the prewetted ship using the conservative figure of 75% for the efficiency of prewetting.

Even allowing for the fact that the radiological yield was greater than 1 KT, the observed dose-rates are somewhat higher than the calculated ones, and it is reasonable to assume that the radioactivity in the sea water used to wash down the ship may have increased the dose rate above what it would have been if the ship had been washed in clean water. No quantitative estimates of the importance of this factor are available, but it seems very significant that this active water was only found within an hour or so of the times when the wind structure suggests that the fallout should have been arriving at the place where DIANA was. It is certain that at least some of the activity came direct from the air, and there is no reason to believe that DIANA would have observed anything very different had she been stationed throughout at the position she occupied at H+7 hours.

The dose rate on the forecastle, which was not prewetted, was of the order of 20 mr/hr, corresponding to a dose to infinity of about 1.3r.

4. ANALYSIS OF DIANA's MOVEMENTS - G2

A post-shot fallout analysis for G2 is shown in Fig. 3. The top of the atomic cloud stabilized at about 48 thousand feet. The points where fallout should have arrived from heights of 8, 16, 24, 32, 40 and 48 thousand feet at times 4, 8 and 12 hours were computed from the wind field as observed over the Montebello Islands and H.M.S. DIANA immediately before firing, and over Onslow and Port Hedland afterwards. The same variation of falling velocity with height as for G1 was assumed, and "centre lines" were drawn in the same way. However, the peculiar wind structure makes calculations of mean densities of fallout rather meaningless, since causes of crosswind scattering other than angular wind shear must have been dominant where H.M.S. DIANA received fallout. The track of H.M.S. DIANA, as reported in Appendix B to Section 1 of Ref. 6, is again plotted as a continuous line, with the times translated into hours and minutes after shot time.

As stated in Section 2, DIANA's station was chosen by D.M.C. Thomas and A.G. Matthewman in an attempt to receive fallout from a height 1000 feet below the centre of the cloud, i.e. from about 35,000 feet. The distance was chosen to give a hypothetical peak total gamma dose in an infinite field of 9 roentgens, rather than the 5 roentgens specified in the Admiralty Instructions, in an effort to obtain more activity than at G1.

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The narrative in Section 1 of Ref. 6 will now be studied in the light of Fig. 3.

"At H+2.06 C.T.F.308 ordered me to take up a new station ... six miles south west of my position at that time. The E.T.A. of the fallout was stated to be H+2.16 - H+2.46.

"I continued on the same course - 065° - while the ship was being closed down and the port shaft disconnected. At H+2.24 course was altered to 085, to obtain efficient prewetting, and at H+2.41 to 205, when the ship was fully closed down and ready to receive fallout.

"This was first detected at H+3.12 and course was altered to 095 and later 105°, with a 20° weave superimposed, so that a relative wind of about 20 knots was obtained varying in direction from Red 20 to Green 20. As the ship was only making about 2 knots through the water, each leg of the weave took four to five minutes.

"As the activity continued to be very slight, instructions were requested from C.T.F.308 at H+5.01. At H+5.42 course was altered to 330 and speed increased to 10 knots, as it was thought that the main fall out probably lay to the North."

Fig. 3 suggests that DIANA received fallout from a wide range of heights over a wide range of times. The fallout at H+3.12 can readily be explained as coming from near the top of the cloud. Fallout will have continued to arrive from progressively lower heights until about H+5.30 when activity may have come from about 35 thousand feet. With all the wind data available, it seems clear that DIANA would have had to move South soon after this in order to receive any more fallout.

However, the post-shot wind data available to C.T.F.308 at H+5.30 were very sketchy. This is why C.T.F.308 concurred with DIANA's action in moving North.

It is clear from Fig. 3 why no further activity was encountered after the move North.

According to Ref. 6, upper deck readings at H+12 hours varied, but in the main were below 10 mr/hr. Since the bulk of the activity arrived at about H+4 hours, this corresponds to a total dose to infinity of just under 1r. on the upper deck of the prewetted ship. It is therefore very near to the original target dose.

The dose rate on the unprewetted forecastle was of the same order as after G1.

5. THE WHALER AND THE DAN BUOY

The Whaler at G1 was anchored at a point 4.8 miles from Ground Zero on a bearing of 353°. The upper wind data suggest that it should have received fallout from a height of about 12 thousand feet. There are two difficulties about estimating theoretically what the density of fallout ought to have been. One is that the U.S. Cloud Model, in common with all other known theories of fallout, is not accurate at such short ranges. The other is that the Northerly component of the low level winds over Montebello decreased from 16 knots at H-1 hr. to zero at H+1 hr. It is therefore difficult to estimate what it was at the relevant time. Linear interpolation leads to the conclusion that the mean time of arrival of the fallout on the whaler should have been about H+55 minutes, i.e. a mean wind speed of 5 knots. On this interpretation of the wind data, the U.S. Cloud Model suggests that the density of the fallout should have been about 0.44 1-hr curies per square metre for each Kiloton radiological yield, and that the fallout should have lasted about 7 minutes.

However, the rotary collector on the whaler shows virtually all the fallout as having arrived 25±2 minutes after the collector started to rotate. It seems probable that the collector started to rotate at H hour, having been set off by flash. It might have been set off later by gamma radiation from the atomic cloud, but it seems preferable to believe that the fallout arrived at H+25 minutes. This requires a mean wind speed of 12 knots, which is not impossible although it is rather higher than the wind data suggest. Assuming such a wind speed, the U.S. Cloud Model suggests that the density of the fallout should have been about 0.74 1-hr. curies per square metre for each kilton radiological yield, and that the fallout should have lasted about 3 minutes, as observed.

Estimates of the density of contamination on the whaler obtained from samples analysed at H+6 days vary from 1.5 to 13 1-hr curies per square metre (depending on the assumed decay rate in the first 6 days). The agreement with theory is as good as one could reasonably expect.

The Dan Buoy for G2 was anchored at a point 7 miles from Ground Zero on a bearing of 303°. The wind data suggest that it should have received fallout from about 13 thousand feet at about H+2¼ hours. The U.S. Cloud Model then suggests that the density of fallout should have been 0.024 1-hr curies per square metre for each kiloton radiological yield, and that the fallout should have lasted about 33 minutes. Unfortunately there are no experimental data to check any of these figures.

6. CONCLUSIONS

It seems fair to claim that the fallout prediction aspect of this trial was extremely successful, and thanks are due to the A.W.R.E. Theoretical Predictions Group for achieving this. Nevertheless there are some lessons to be learned about the planning of such a trial in the light of our present knowledge of fallout.

The primary lesson seems to be that the instructions concerning the stationing of the ship should be made more flexible, details being decided in the light of the actual upper wind structure. This applies both to the direction from ground zero, and also to the intended amount of fallout to be received, since different safety factors are appropriate in different conditions. This last point is very important and should be elaborated.

When the mean wind direction changes fairly rapidly with height, and in a consistent direction, as at G1, one's estimates of the peak density of contamination at a given distance are likely to be much more accurate than in other conditions, such as G2, where small changes in the winds can have an appreciable effect on the fallout pattern, and where causes of cross-wind spread other than angular wind shear are important. Although Ref. 3 suggests that one should allow for possible errors of a factor of 10 in the peak dose-rate in these cases, a factor of 4 may well be adequate in G1 conditions even allowing for uncertainty in yield.

The other vital question affecting safety factors is the extent to which the ship can steam out of unexpectedly high contamination. This depends largely on the rate of advance of the centre line of the contamination falling at a given time. If this rate, measured at right angles to the centre line, is u knots, and if the ship's speed is v knots, then the ship can reduce contamination to a fraction u/(u+v) of what it would be on a stationary ship by steaming across the centre line towards the side of earlier times. Therefore if u is small, say 5, the ship has a substantial safety factor under its own control which is absent if u is say 30. When u is small, the ship can also try to travel with the fallout, remaining on the centre-line for a long time and building up the required density of contamination gradually.

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This technique has been used by the Americans. However, small values of u may well be associated with activity apparently in the sea rather than in the air, as at G1, which may be unsatisfactory for some purposes.

It has been suggested that the safety precautions at MOSAIC were unduly strict, since no member of the ship's company received a measurable gamma dose, even though the intended degree of contamination of the upper deck was achieved. It may be that the shielding factor of $\frac{1}{2}$ attributed to the ship's structure was conservative. But one important cause of this happy result was undoubtedly the fact that the ship was fairly thoroughly decontaminated within a few hours of the arrival of the fallout. Before raising the intended upper deck contamination appreciably, one would want to be sure that early decontamination was feasible even when the initial contamination is much more severe. The consequences of increased contamination of the boiler room and machinery spaces would also have to be considered.

This matter can perhaps be summarized by saying that the intended amount of fallout could be increased by a factor of 10 in favourable circumstances if necessary, but that an increase by a factor of 100 does not seem justified.

On the administrative side, it seems reasonable to hope that the group responsible for fallout predictions from a radiological safety point of view could advise on the stationing of the ship, as at MOSAIC. The Admiralty would have to issue detailed instructions concerning the densities of fallout to be aimed at in different circumstances, or else an Admiralty authority would have to be present to advise on this matter.

Another important question is the amount of wind data required to produce an adequate fallout analysis. One striking feature of the present work is the extent to which the calculated fallout patterns fit in with DIANA's observations, even though the calculations are based on a rather sparse network of wind-finding stations. This suggests that even a small number of post-shot upper wind ascents can be a great help in an operation of this kind, provided that the information can be sent to the authority controlling the ship's movements quickly, and provided that the authority can communicate quickly with the ship.

If the ship is prepared for extensive post-shot manoeuvrings to intercept the fallout, one can of course do much to reduce the danger of her missing it altogether. The detailed procedure clearly depends on the wind structure, but in general it will be best to first seek fallout from a height to which the mean wind speed is high, so that if this fails there will still be time to seek it from heights to which the mean wind speed is lower.

7. ACKNOWLEDGEMENTS

I am grateful to Miss M. Cornes for computational assistance, and to Dr. S.C. Ellis, Mr. J.D. Macdougall, Mr. D.T.G. Morgan and Mr. D.M.C. Thomas for valuable comments on the first draft of this report.

E.M.L. BEALE, S.S.O.

EMLB/BS
A.R.L. Teddington.

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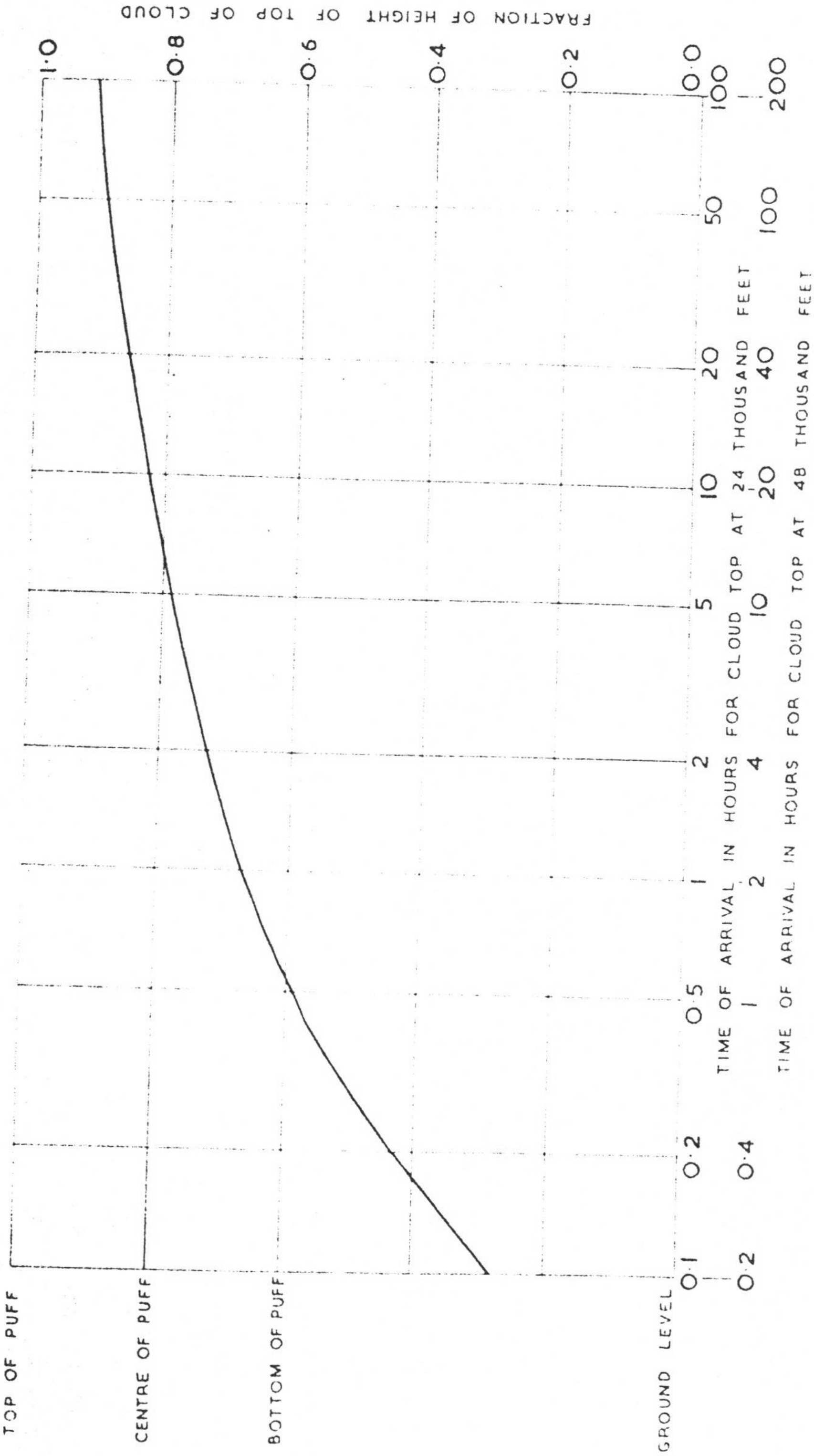
SECRET-DISCREET



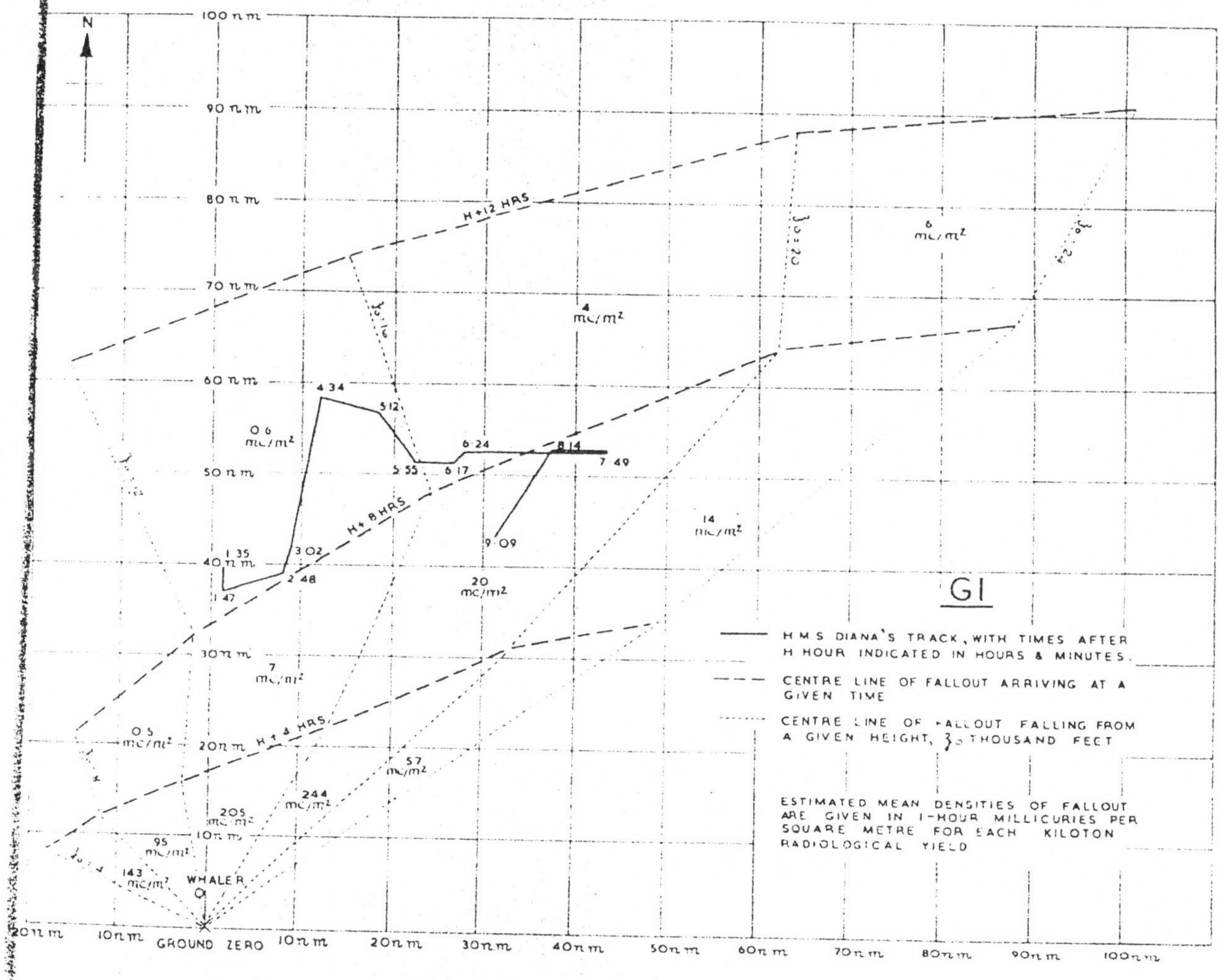
MEAN HEIGHT OF ORIGIN OF CONTAMINATION FALLING AT A GIVEN TIME.

A.R.L/R3/C791

FIG. 1

SECRET - DISCREET

SECRET-DISCREET

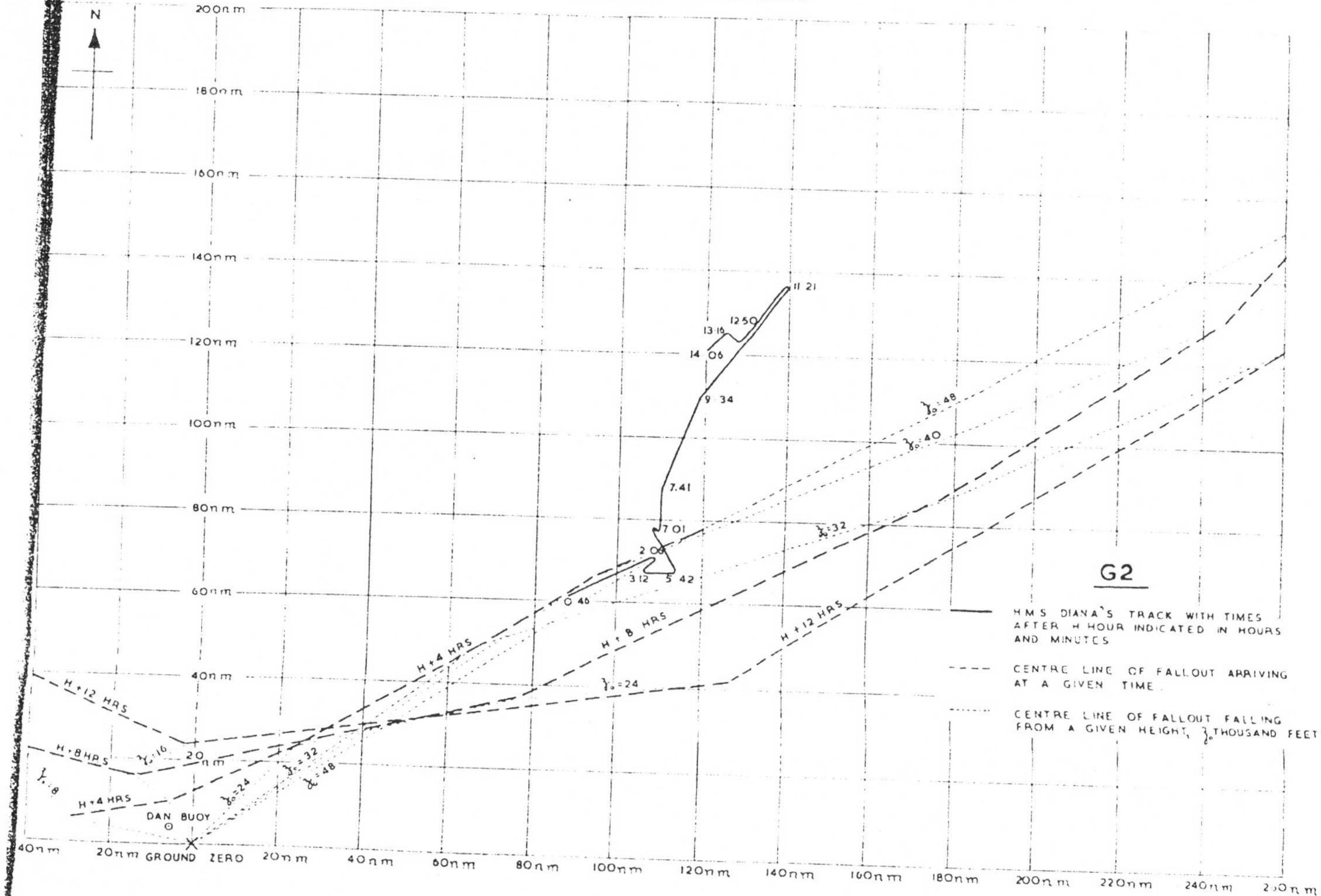


A R.L/R3/C791

SECRET-DISCREET

FIG. 2

SECRET-DISCREET



A.R.L./R3/C791

SECRET-DISCREET

FIG. 3

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