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UK ABWR

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UK ABWR Generic Design Assessment

Approach to Sampling and Monitoring

Hitachi-GE Nuclear Energy, Ltd.

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1. Acronyms

ABWR	Advanced Boiling Water Reactor
BAT	Best Available Technique
BWR	Boiling Water Reactor
EPR	Environmental Permitting Regulations
EU	European Union
GEP	Generic Environmental Permit
GEP-RSR	Generic Environmental Permit - Radioactive Substances Regulation
GDA	Generic Design Assessment
HFE	Human Factors Engineering
HMIP	Her Majesty's Inspectorate of Pollution
HMSO	Her Majesty's Stationery Office
HP	High pressure
HVAC	Heating Ventilation and Air Conditioning System
IPPC	Integrated Pollution Prevention and Control
LP	Low pressure
MCERTS	Monitoring Certification Scheme
OSPAR	Oslo and Paris Convention on Protection of the Marine Environment of the North East Atlantic
P&ID	Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Design
PCSR	Pre-Construction Safety Report
PSR	Preliminary Safety Report
R/B	Reactor Building
REPs	Radioactive Substances Regulation - Environmental Principles
RGP	Relevant Good Practice
RSR	Radioactive Substances Regulation
SGTS	Standby Gas Treatment System
SJAE	Steam Jet Air Ejector
T/B	Turbine Building

2. References

1 Process and Information Document for the Generic Assessment of Candidate Nuclear Power Plant Designs, Version 2, Environment Agency, March 2013.

2 Environmental Permitting Regulations (England and Wales) Regulations 2010 (SI 2010 No.675), The Stationery Office.

3 Approach to Optimisation, GA91-9901-0021-00001, XE-GD-0096, Rev C, Hitachi-GE, March 2014.

4 Demonstration of BAT, GA91-9901-0023-00001, XE-GD-0097, Rev C, Hitachi-GE, March 2014.

5 Monitoring of Radioactive Releases to Atmosphere from Nuclear Facilities. Technical Guidance Note (Monitoring) M11, Environment Agency, 1999a.

6 Monitoring of Radioactive Releases to Water from Nuclear Facilities Technical Guidance Note (Monitoring) M12, Environment Agency, 1999b.

7 Routine measurement of gamma ray air kerma rate in the environment, Technical Guidance Note (Monitoring) M5, HMIP, HMSO, Environment Agency, 1995.

8 Commission verification of facilities in Member States which carry out continuous monitoring of levels of radioactivity in air, water and soil, Euratom, 2006.

9 Regulatory Guidance Series, No RSR 1; Radioactive Substances Regulation – Environmental Principles; Version 2; April 2010.

10 Consideration of and Compliance with the Radioactive Substances Regulation Environmental Principles (REPs), GA91-9901-0028-00001, XE-GD-0099, Rev C, Hitachi-GE, March 2014.

11 Radioactive Waste Management Arrangements, GA91-9901-0022-00001, WE-GD-0001, Rev C, Hitachi-GE, March 2014.

12 Prospective Dose Modelling, GA91-9901-0026-00001, HE-GD-0005, Rev. C, Hitachi-GE, March 2014.

13 Categorisation and Classification of Systems, Structures and Components, GA91-9901-0007-00001, XE-GD-0104, Rev B, Hitachi-GE, 14th March 2014.

14 Commission recommendation on standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation, Euratom, 2004.

15 Radiological Monitoring Technical Guidance Note 1, Environment Agency & SEPA, 2010.

16 Radiological Monitoring Technical Guidance Note 2, Environment Agency & SEPA, 2010.

17 Sampling requirements for stack emission monitoring Technical Guidance Note (Monitoring) M1, Environment Agency, 2010d.

18 MCERTS: Performance Standard for Organisations Undertaking Radioanalytical Testing of Environmental and Waste Waters, Environment Agency, 2012e.

19 Minimum Requirements for the Self-Monitoring of Effluent Flow, Version 3.5, Environment Agency, 2013.

20 Useful background information and more interpretation from the Environment Agency, Environment Agency, Presentation 2012.

21 Preliminary Safety Report on C&I, GA91-9901-0001-00001, XE-GD-0107, Rev B, Hitachi-GE, March 2014.

3. Introduction

The Environment Agency's requirements for the provision of information in the GDA submission are defined within their Process and Information Document (P&ID) (1). This stipulates the necessary information relating to sampling arrangements, as well as techniques and systems for measurement and assessment of discharges and disposals of radioactive waste.

At this stage of the GDA process, it is not yet possible to provide precise details on what sampling, measurement and monitoring will be installed in the UK ABWR. This document will ultimately describe, at a high level, the approach that will be taken in determining the sampling, measurement and monitoring design in the UK ABWR in support of operations. Further information will be provided during later stages of the GDA process as the design develops and, in some instances where it falls to the responsibility of the operator, information will be developed following GDA as part of the site-specific permitting application.

Once completed, the systems identified will allow the measuring of performance against what is deemed to be Best Available Technique (BAT), as well as the recording of discharges into the environment.

In this submission a high level approach to sampling and monitoring is described, with focus on the radiological effluent sampling and monitoring. Details of non-radiological sampling and monitoring arrangements will be described in the later GDA steps.

An environmental monitoring programme is not included within the GDA submission due to the site-specific nature of the programme that will be developed. Environmental monitoring regimes vary from site to site as they are developed to reflect local conditions such as the critical group, local flora and fauna and the operating conditions of the site. Hitachi-GE is committed to making sure that the future site operators will have a well-developed and meaningful environmental monitoring programme and will work with potential future operators to this effect.

4. Regulatory Requirements

4.1. P&ID requirements

The Environment Agency has identified the information they require to carry out the GDA process in the P&ID (1). The P&ID requirements relating to sampling arrangements, techniques and systems for measurement and assessment of discharges and disposals of radioactive waste are reproduced below:

> *A description of the sampling arrangements, techniques and systems for measurement and assessment of discharges and disposals of radioactive waste.*
>
> *Include:*
> - *details of in-process monitoring arrangements, as well as those for final discharges of gaseous and aqueous wastes, and disposals of non-aqueous liquid and solid wastes;*
> - *a demonstration that your proposals represent the best available techniques for monitoring;*
> - *confirmation that the sensitivity is sufficient to:*
>   - *readily demonstrate compliance with the proposed limits;*
>   - *meet the levels of detection specified in reference EU, 2004.*

4.2. Legislative Context

The main area of legislative requirements relevant to this section of the P&ID is the Environmental Permitting Regulations 2010 (as amended) (EPR 10) (2).

A further requirement on nuclear licensed sites in England and Wales is BAT is used for monitoring discharges. The concept of BAT is defined in the OSPAR convention and in Directive 1996/61/EC on Integrated Pollution Prevention and Control (IPPC). Further information on Hitachi-GE's approach to assessing and demonstrating BAT are provided in other areas of the GEP submission (3) (4).

Various pieces of regulatory guidance have also been reviewed in the developing of this element of the GDA GEP submission. These are listed in full in Section 2 References. Technical Guidance Notes M11 (5) M12 (6) and M5 (7) are undergoing revision and the draft versions that have been circulated for consultation have also been considered.

Article 35 of the Euratom Treaty (8) requires not only self-monitoring of the levels of radioactivity in nuclear facilities but also the independent verification of the operation and efficiency from proper authorities.

4.3. REPs Applicable to Sampling, Measurement and Assessment

The sampling and monitoring arrangements that will be presented in this report will be consistent with industry Relevant Good Practice (RGP) and take into account the relevant Radioactive Substances Regulation – Environmental Principles (REPs) (9). Hitachi-GE's 'Consideration of and Compliance with the Radioactive Substances Regulation Environmental Principles (REPs)' report (10) details the approach undertaken by Hitachi-GE to reviewing and showing compliance with each of the relevant REPs within the GDA submission, highlighting the REPs specifically addressed in each report.

Principally, this report addresses RSMDP13 as well as ENDP4, ENDP10 and ENDP14, in presenting a sampling and monitoring system that is consistent with relevant guidance standards and uses BAT to quantify and control the gaseous and liquid radioactive discharges.

5. Measuring performance against BAT

Hitachi-GE recognises that the description of the sampling arrangements, techniques and systems for measurement and assessment of discharges and disposals of radioactive waste is an important aspect of the GDA process and commit to providing the information as part of the GDA.

At this moment in time it is difficult to be certain about the actual monitoring arrangements that will be deployed for the UK ABWR as the technology selection is influenced by the demonstration of BAT, the selection of radionuclides for limits, the need for information on plant performance and the final plant design/layout. However, at this stage of the process, Hitachi-GE can make a series of commitments and ensure that they are adhered to as the Safety Case and Design progresses. These high level design principles are:

1. The design allows for data (regarding radioactivity, radionuclide composition, and volume) to be measured and collected to ensure permit condition compliance, during both operation and maintenance.

2. All routes for radioactive discharges under normal operations (e.g. main stack and main outfall) to the environment are identified and monitored to obtain entire discharge data. Non-radioactive discharge points or paths where radioactive substances are not found are not monitored, unless required for demonstrating plant performance.

3. The need for continuous monitoring is incorporated into the design in order to record temporal fluctuations of the discharge levels.

4. Provision for grab sampling is made, allowing detailed analyses to supply relevant nuclide-specific data which is essential for demonstrating compliance.

5. For batch discharge points, provision is made for samples to be collected for analysis prior to discharge. Additionally, the provision for continuous monitoring is included within the design to prevent human error.

6. The design allows for various radiation detectors to be used so that those considered BAT can be selected at the time with sufficient sensitivity to support permit condition compliance.

7. The system is designed to obtain representative samples whose radioactive concentration is equivalent to the process fluid.

8. Locations for in-process monitoring and sampling arrangements are included to allow equipment to be installed that can help identify when operations deviate away from that considered to be BAT.

9. Transfer of on-site stored radioactive wastes (e.g. solid wastes) to the proper authorities (11) is allowed once the levels have been reviewed and approved as suitable for acceptance.

10. Automatic interlocks are designed based on Human Factors Engineering (HFE). An unexpected radioactive release sequence is faster than human judgments and operations and is therefore automatically stopped upon detecting the high radiation level.

Hitachi-GE have developed information to underpin the proposal of limits for the UK ABWR in GDA, and have carried out prospective dose modelling at these limits to show that the doses to members of the public and non-human species are very low (12). The environmental monitoring will be carried out during the operational phase of the site to verify that this is the case.

6. Categorisation and Classification of equipment

All the equipment in the UK ABWR, including sampling and monitoring equipment will be categorised and classified according to their safety functions. The procedure used for categorisation is described in the PSR (13) and associated PCSR.

The categorisation and classification of equipment will continue as the PCSR develops, and may impact upon the sampling and monitoring regime deployed in the UK ABWR. These refinements will be included in later GDA steps.

7. Description of equipment to be included within GDA

This section has not been completed for GDA step 1b and will be described in more detail in later GDA steps. The focus of this section will be on the main process areas, the monitoring systems and detection limits of equipment.

For the final discharge points to the environment, the GDA design will include provision for independent monitoring points, namely sampling ports, to satisfy Environment Agency requirements for new nuclear power stations.

The standard ABWR design information shown in Appendix A is for information only at this stage.

8. Conclusion

This document describes, at a high level, the design principles for the sampling, measurement and monitoring regime that will be included in the UK ABWR design. In the next step of GDA, the fundamental design of the UK ABWR will be described in connection with these principles. As a guide only, the standard ABWR sampling and monitoring design information is shown in Appendix A.

The information to be provided in later steps of GDA will include:

- Details of in-process monitoring arrangements, as well as those for final discharges of gaseous and aqueous wastes, and disposals of non-aqueous liquid and solid wastes;
- A demonstration that the proposals represent BAT for monitoring;
- Confirmation that the sensitivity is sufficient to:
    - readily demonstrate compliance with the proposed limits;
    - meet the levels of detection specified in reference EU, 2004.

Appendix A: Standard ABWR design information

At this stage of GDA it is not possible to give precise details on what sampling, measurement and monitoring will be installed in the UK ABWR. However, the standard ABWR design is described here as additional background information for the Environment Agency and interested parties.

1. Description of equipment to be included within GDA

One of the main objectives of the radiation monitoring system is to provide operating personnel with measurements of radioactive material contained in effluent process streams. This demonstrates compliance with plant normal operational technical specifications by providing gross radiation level monitoring and by the collection of particulates and halogens on filters (for gaseous effluents). Additional objectives are to initiate discharge valve isolation on the liquid radwaste system if predetermined release rates are exceeded, and to provide for sampling at certain radiation monitor locations to allow determination of specific radionuclide content. Major monitoring points and sampling points are shown in Figure A. 3-1.

2. Main process areas and systems

2.1. Main Stack Discharge Radiation Monitoring

This subsystem monitors the main stack discharge for gross radiation level during normal plant operation and collects particulate, halogen, and vapour condensed water samples for laboratory analyses. The discharge includes off-gas, turbine gland seal off-gas, HVAC exhausts from the secondary containment and turbine building controlled areas. A representative sample is continuously extracted from the main stack through an isokinetic probe, passed through the sample panels for monitoring and sampling, and returned to the main stack.

The radiation detector assembly consists of a shielded gas chamber that houses a scintillation detector and a check source. A radiation monitor in the main control room analyses and visually displays the measured radiation level. If the system detects an anomaly, it activates an alarm in the main control room to warn operating personnel. In-process radiation monitors can provide a trace of the source. A redundant system is also available to avoid a lack of measurement under single failure.

The gas shielded chambers can be purged with room air from the control room. The gas chamber is equipped with a check source to test detector response to background radiation, thus checking operability of the radiation channel. The sample panel has a pair of filters: one for particulate collection and one for halogen collection. The sampled gas is chilled to obtain vapour condensed water for the tritium measurement; these samples are analysed in detail at the on-site laboratory.

2.2. Radwaste Liquid Discharge Radiation Monitoring

This subsystem continuously monitors the gross radiation level in the radioactive liquid waste at the final discharge path during its discharge to the environment and stops the discharge upon high radiation level.

Liquid waste is discharged from the sample tanks containing liquids that have been processed through one or more treatments. Before the discharge, the sufficiently mixed liquid is sampled from the recirculation line and analysed in the laboratory. The liquid waste is allowed to be discharged only if the radioactivity levels are below effluent release limits.

A radiation monitor is provided in the liquid discharge line as a countermeasure to human error. If the system detects an anomaly, it activates an alarm and closes an isolation valve to stop the discharge to the environment. An alarm and interlock level is set in the viewpoint of the anomaly detection independently of effluent release limits.

2.3. In-process Radiation Monitoring

The off-gas and turbine gland seal off-gas are continuously monitored before they feed to the main stack as shown in Figure A. 3-1. For the sake of nuclide analyses, grab sampling provisions are considered.

The HVAC exhaust is not independently monitored before the junction to the main stack (because the radiation level of the HVAC exhaust is extremely low) but monitored at the main stack in total. The required monitoring is significant, not because of the discharge to the environment, but rather the potential for radiation exposure to personnel (countermeasures to which are described in the PCSR). If an increase of the radiation level in the HVAC exhaust is detected by the main stack radiation monitor, then operating personnel can identify the appropriate stream by eliminating the other two tributaries: off-gas and turbine gland seal off-gas.

Note that the standby gas treatment system is operated only under accident conditions, and therefore out of scope of the GEP application.

2.4. Off-gas Radiation Monitor

Under normal operation of the power plant, the major radioactive gas waste is from the off-gas system. Its main components are the fission-produced noble gases barely and design tolerantly released from fuel cladding tubes under routine conditions. The off-gas is treated in the gaseous waste management system where noble gases are held up on charcoal adsorbers for a certain time. Short lived radionuclides decay within the hold-up time and so the amount of radioactive waste gas discharged to the environment is decreased. In the standard ABWR, the inlet and outlet of the gaseous waste management system are monitored.

At inlet of the gaseous waste management system, a radiation detector is provided. This continuously measures gross radiation level of the pre-treated off-gas which corresponds to the amount of the noble gas leaked from the fuel cladding tubes. A radiation monitor in the main control room analyses and visually displays the measured radiation level. If the system detects an anomaly, it activates an alarm in the main control room. A grab sampling provision is also provided for an advanced analysis to obtain the radionuclide composition.

At outlet of the system there is similar equipment as provided at the system inlet. A radiation detector continuously measures the gross radiation level of the post-treated off-gas which is fed to the main stack to be discharged to the environment. A radiation monitor in the main control room analyses and visually displays the measured radiation level. If the system detects an anomaly, it activates an alarm in the main control room to warn operating personnel to isolate the discharge line. A grab sampling provision is also provided. Results of these nuclide analyses are essential inputs for the evaluation of the total radionuclide composition to be discharged to the environment.

2.5. Turbine gland seal off-gas monitor

Turbine gland seal off-gas is continuously discharged to the environment through the main stack under normal operation. The system monitors the outlet of the turbine gland steam system where a radiation detector is located. This detector continuously measures the gross radiation level of the turbine gland seal off-gas which concerns with main steam leaks from seal locations. A radiation monitor in the main control room analyses and visually displays the measured radiation level. If the system detects an anomaly, it activates an alarm in the main control room. A grab sampling provision is also provided for an advanced analysis.

3. Detection limit

The detection limit of the system depends on some factors such as sample preparation, effective volume of radioactive substance and detector sensitivity. Sensitivities of radiation monitors placed at the continuous discharge points ensure compliance with the actual effluent release limits, which are typically set one order of magnitude lower than the permitted release limit. The detection limit for batch discharge points are designed independently with the release limits. The laboratory equipment has the highest industrially available sensitivity in order to monitor even slight differences.

The detection limits are specified for key nuclides in EU 2004 (14). The requirements are compared with the standard ABWR typical detection performance, as obtained via operational experience in Table A. 3-1 and 3-2.The typical detection limits depend on the sample preparations and measurement conditions and therefore the limits could be changed. There is flexibility for operators to change conditions for their requirements.

The standard ABWR already complies with the majority of the EU 2004 requirements, as shown in Table A. 3-1 and 3-2, though the following should be noted:

i. For Kr-85, EU 2004 gives the limit of beta measurement, while standard ABWR data shows the limit of continuous gamma measurement. As mentioned previously, the standard ABWR continuously monitors radioactive gas discharge by measuring gross gamma radiations. Nuclide composition of the effluent gas is evaluated in advance, therefore a separate Kr-85 specific measurement is not necessary.

ii. In EU 2004, Pu and Am measurements are not stipulated as necessary: if nuclide-specific information on alpha-emitters is not available, total alpha measurements can be substituted instead.

iii. In the standard ABWR, C-14 is not measured because, as calculated by the radiation dose assessment, its impact is negligible. To evaluate internal radiation exposure, total beta measurements are carried out.

iv. The detection performance of the total alpha measurement for liquid samples does not meet with the requirements of EU 2004 (14). Performance of the detector depends on the processes used in sample preparation and the measurement condition. It is expected that the detection limit can decrease down to the compliance level if the measurement condition is improved.

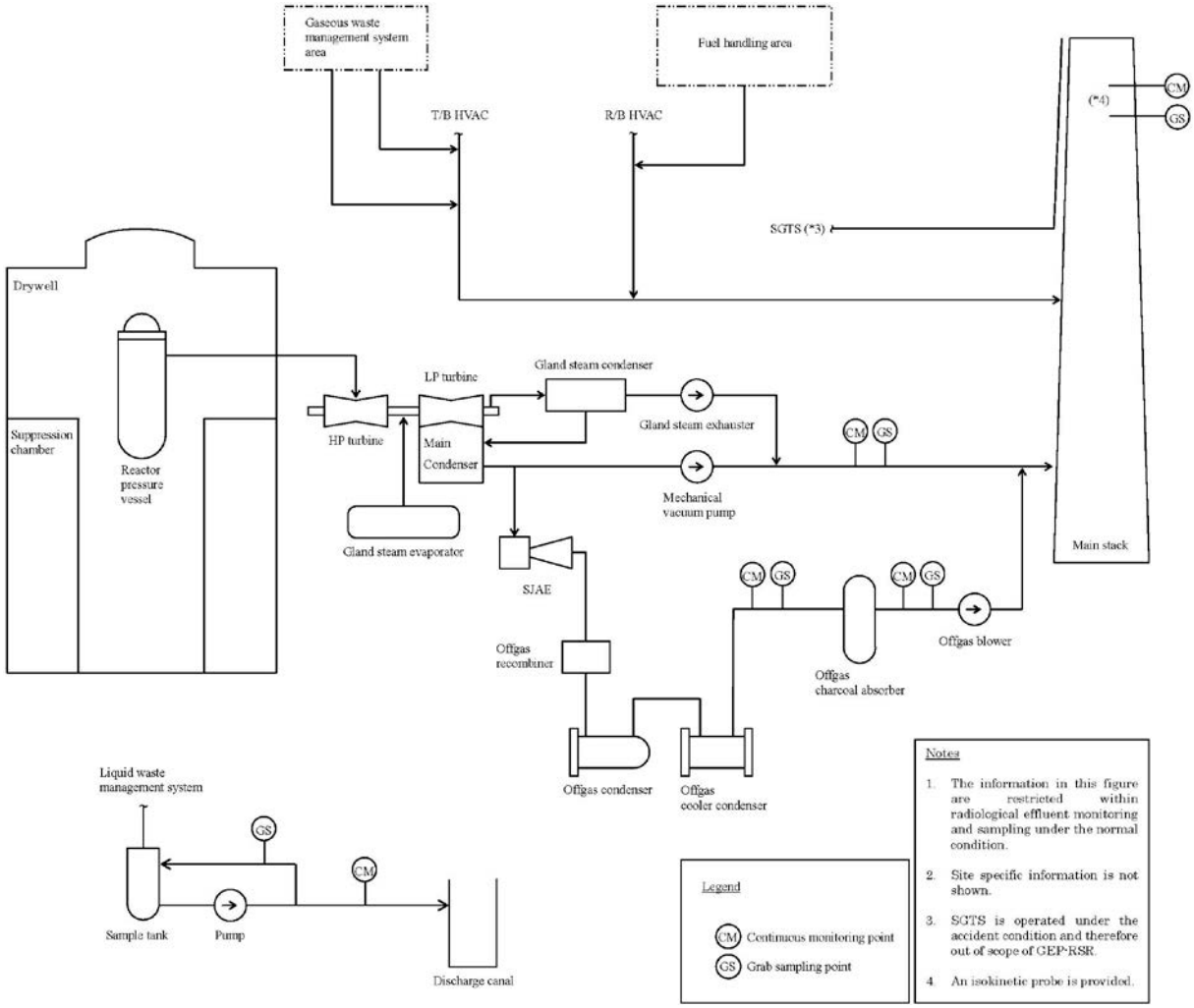

Figure A. 3-1: Typical monitoring and sampling points for standard ABWR

Table A. 3-1: Standard ABWR compliance with EU 2004 (gas)

EU 2004		Standard ABWR	
Key nuclides	**Requirements for the detection limit (Bq/cm^3)**	**Nuclides**	**Typical detection performance (Bq/cm^3)**
Kr-85	1E-2	Noble gas (total)	2E-2
Co-60	1E-8	Co-60	4E-9
Sr-90	2E-8	Sr-90	4E-10
Cs-137	3E-8	Cs-137	< 3E-8
(Pu-239 + Pu-240)	5E-9	(Pu-239 + Pu-240)	-
(Am-241)	5E-9	(Am-241)	-
Alpha (total)	1E-8	Alpha (total)	4E-10
I-131	2E-8	I-131	7E-9
H-3	1E-3	H-3	4E-5
C-14	1E-5	Beta (total)	4E-9

Table A. 3-2: Standard ABWR compliance with EU2004 (liquid)

EU 2004		Standard ABWR	
Key nuclides	**Requirements for the detection limit (Bq/cm^3)**	**Nuclides**	**Typical detection performance (Bq/cm^3)**
H-3	1E-1	H-3	< 1E-1
Co-60	1E-2	Co-60	≤ 1E-2
Sr-90	1E-3	Sr-90	7E-4
Cs-137	1E-2	Cs-137	≤ 1E-2
(Pu-239 + Pu-240)	6E-3	(Pu-239 + Pu-240)	-
(Am-241)	5E-5	(Am-241)	-
Alpha (total)	1E-3	Alpha (total)	4E-3