Darlington Target Delivery System Human Factors Engineering Program Plan (HFEPP) – MEC 166617

Document No. 705-2466250300-PLA-G0001-02
Client Doc No. NK38-PLAN-30550-00106 R000
November 01, 2024

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REVISION HISTORY

REV. NO.	ISSUE DATE	PREPARED BY AND DATE	REVIEWED BY AND DATE	APPROVED BY AND DATE	DESCRIPTION OF REVISION
R000	Nov 01, 2024	Agata Lawrynczyk Nov 01, 2024	Stephanie Piva Nov 01, 2024	Sujit Brahma Nov 01, 2024	Initial Issue. Note that this document was co-prepared by Roelant Lobbezoo.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
AA	Adjuster Absorber
AFS	Available for Service
AOF	Allocation of Function
AR	Action Request
DBA	Design Basis Accidents
CNP	Canadian Nuclear Partners
CNSC	Canadian Nuclear Safety Commission
COG	Candu Owners Group
COMS	Constructability, Operability, Maintainability and Safety
CSA	Canadian Standards Association
DEC	Design Engineering Change
DNGS	Darlington Nuclear Generating Station
DV	Design Verification
EHS	Environmental, Health and Safety
FA	Functional Analysis
FAT	Factory Acceptance Test
FIC	Field Initiated Change
HFE	Human Factors Engineering
HFEPP	Human Factors Engineering Program Plan
HFESR	Human Factors Engineering Summary Report
HFVVP	Human Factors Engineering Verification and Validation Plan
HMI	Human Machine Interface
HSI	Human-System Interface
HTA	Hierarchical Task Analysis
ITF	Issues Tracking File
MEC	Master Engineering Change
MOU	Memorandum of Understanding
MSC	Minimum Shift Complement
NEC	Nuclear Energy Canada
OER	Operating Experience Review
OPEX	Operating Experience
OPG	Ontario Power Generation
RMD	Reactivity Mechanism Deck

Acronyms/Abbreviations	Definition
SCR	Station Condition Record
SME	Subject Matter Expert
TA	Task Analysis
TDS	Target Delivery System
TEL	Target Elevator
TSV	Task-Support Verification
V&V	Verification and Validation

1.0 INTRODUCTION

This document is the Human Factors Engineering Program Plan (HFEPP) for the Darlington Nuclear Generating Station (DNGS) isotope production Target Delivery System (TDS) for Unit 3. The purpose of the system is to produce isotopes for medical applications by irradiation of natural products.

A HFEPP, NK38-PLAN-30550-00002 R002, Darlington Target Delivery System Human Factors Engineering Program Plan [1], was previously issued for design / implementation of the TDS on Unit 2 and Unit 4. For consistency and alignment of the documentation between units, this Unit 3 HFEPP takes information from the previous HFEPP where appropriate.

1.1 PROJECT BACKGROUND

Canadian Nuclear Partners (CNP) has entered into a Memorandum of Understanding (MOU) with BWXT to utilize Ontario Power Generation (OPG) reactors for the irradiation of material used to generate isotopes for end use in the medical industry. DNGS has been chosen as the location for the installation of a system designed to irradiate molybdenum in the reactor core. In order to implement the TDS at DNGS, a number of modifications and new equipment are required.

Based on walkdowns and investigations at OPG's facilities, it was determined that the optimal method to access the required flux fields within the reactor core was by penetrating reactor containment vertically at the Reactivity Mechanism Deck (RMD) at DNGS. Out-of-service Adjuster Ports are to be utilized as the chosen access ports and will be modified to house the necessary modifications needed to support the Mo irradiation process. Due to the radioactive properties of irradiated isotopes, a shielded transfer system has been designed that is capable of delivering targets into the target elevators and of retrieving the irradiated material. The irradiated targets must be contained within a shielded flask for transport [2].

The project scope includes the engineering design, build, manufacturing, installation and commissioning of the TDS within DNGS Unit 3. Human Factors Engineering (HFE) will be fully integrated within the scope outlined in Section 1.3. Initially, the TDS design effort focused on Unit 4. However, it was decided that TDS would first be installed on Unit 2 which has since been placed in service, while Unit 4 was placed on hold. Essentially, the Unit 3 system design will be a replication of the Unit 2 design. It is noted that some of the analysis referenced for Unit 2 was initially prepared for Unit 4 with the assumption that they would be applicable to all units.

Table 1 summarizes the TDS HFE reports issued to date, with reference to the applicable Unit design at the time of issuance. The sections in 3.0 further describe which HFE reports will be used to extract the base analysis that will be used for Unit 3.

Table 1: TDS HFE Work Done to Date

Report	Unit
NK38-REP-30550-0763175 R000, Darlington TDS HFE 40% Detailed Design Report [3]	Unit 4
NK38-REP-30550-0786795 R000, Darlington TDS HFE Detailed Design Interim Report [4]	Unit 4

Report	Unit
NK38-REP-30550-00025 R000, Darlington TDS Human Factors Engineering Summary Report (HFESR) [5]	Unit 2
NK38-REP-30550-00039 R000, Darlington TDS HFE Interim Validation Report [6]	Unit 2
NK38-REP-30550-00025 ADD-001 R000, Darlington TDS HFESR Addendum-001 [7]	Unit 2
NK38-REP-30550-00025 ADD-002 R000, Darlington TDS HFESR Addendum-002 [8]	Unit 2

1.2 PURPOSE

A requirement of any modification to nuclear plants is to include adequate consideration of HFE, as mandated by Canadian Nuclear Safety Commission (CNSC) REGDOC-2.5.1, Physical Design General Design Considerations: Human Factors [9]. The purpose of this HFEPP is to define the scope of the HFE activities for the DNGS TDS Unit 3 project (Master Engineering Change (MEC) 166617) and describe the planned approach for the effective management of those activities and timely integration of HFE into the design.

1.3 SCOPE

Human Factors are to be considered in all aspects of the TDS which have a potential impact on nuclear and/or personnel safety. As described in N-FORM-10580 'Identifying Human Factors Level of Effort' of the modification package, the scope of MEC 166617 is to install a TDS for the DNGS Unit 3, which is a replication to the Unit 2 design. The TDS design replication will incorporate OPEX and Lessons Learned from the Unit 2 design and operation, and will assess changes from the Unit 2 TDS design to adapt to DNGS Unit 3.

Furthermore, the TDS design also includes a TDS Tooling Scope, and the scope for Adjuster Absorber (AA) rods removal. For the tooling scope, MEC 143646 was prepared for the design of auxiliary equipment and tooling determined by BWXT as required for activities related to installation, setup, maintenance, and contingency operations of the TDS for Unit 2. For Unit 3, the scope of this tooling is included within MEC 143646 and is limited to updating the design of specific tools to support the installation of the TDS in Unit 3[1]. As for the AA rod removal scope for Unit 3, it is included under this MEC. It includes removal of the AA rods, the AA drive mechanism, the associated Logic Modules and cables, and the Main Control Room updates to remove indication of AA1, AA8, AA17, and AA24. This is unlike that equivalent scope for Unit 2 and Unit 4 AA rod removal which were

[1] At the time of preparation of this HFEPP, the expectation is that there will be administrative changes only to some of the design documentation to include their applicability to Unit 3. With no changes anticipated for the design of auxiliary equipment and tooling (equivalent to MEC 143646), Table 2 does not include a planned DEC related to this scope.

covered under MECs separate from TDS scope (MEC 153746 for Unit 2 and MEC 143546 for Unit 4).

MEC 166617 contains twelve (12) Design Engineering Changes (DECs), noted in Table 2. All twelve DECs are in scope for HFE.

Table 2: DECs for MEC 166617

DEC #	Description
166757	AA Drive Mechanism & Rod Removal for the Moly-99 Project
166758	I&C Hardware – Removal of Logic Modules, Cables, and Control Room Mods for TDS
166759	TDS Contaminated Exhaust Tie-In
166760	TDS Class 3 Power Tie-In
166763	TDS OH180 (Instrumentation and Control) Design
166766	TDS Cable Tray Design
166767	TDS Handrails and Access Gates
166768	TDS Lighting
166769	TDS End Shield Cooling Expansion Tank and Air System Piping Relocation Modification (R3-302)
166770	TDS End Shield Cooling Piping Relocation (R3-301)
166771	TDS Mechanical and Civil Design
166776	TDS Main Control Room and Control Equipment Room Design

At a high-level the HFE scope of work on this project is as follows:

1. Development of a HFEPP (this document)
2. Participation in Constructability, Operability, Maintainability and Safety (COMS) process
3. Completion of required HFE activities (see Section 3.0)
4. Based on the above activities, provision and tracking of HFEs input to design in the form of HFE Issues & Recommendations (see Section 4.0)
5. Documentation of the above activities, issues, recommendations and the associated resolutions in the HFESR.

At the time of issuing this plan, the following design differences, at a minimum, are expected in the TDS Unit 3 design, compared to Unit 2:

1. NF Transfer Frame: NF transfer frame modifications are required to shorten the frame assembly height so that the flight tubes and shielding can remain in the same location. This limits changes to the rest of the transfer system and piping.

2. Airlock Platform: Design of the bolted joint connections along with the seismic braces connections to the platform are being updated in order to bring the assembly into compliance with CSA-S16-14.
3. Target Elevator (TEL) Cladding: A series of internal tungsten components within the TELs are being changed from electroless nickel plating to stainless steel cladding.

1.4 EXCLUSIONS AND ASSUMPTIONS

The HFE scope of work does not include assessment of conventional occupational health & safety matters. The scope includes consideration for physical accessibility for the purpose of determining the feasibility of required field actions. In the event that HFE analysis reveals potential conventional safety or ergonomic issues above and beyond the scope of this HFEPP, including OPG design guides, both BWXT Nuclear Energy Canda (NEC) Environmental, Health and Safety (EHS) department and OPG Conventional Health and Safety will be consulted, an appropriate resolution determined and documented in the HFESR.

For the purposes of this HFEPP, it is assumed that Fuel & Physics will be responsible for assessing reactivity changes associated with the TDS. The associated analyses and planning work are outside the scope of HFE [1].

Cobalt production is not part of the present scope of work but is an interfacing modification. At the time of writing this HFEPP, the anticipated extent of HFE activities related to the Cobalt Adjuster Element System is to confirm that the TDS on-deck components do not interfere with, or can be removed to accommodate, the cobalt flask footprint and travel path. Specific functions, tasks, etc. associated with cobalt production will not be analyzed in detail as these analyses have been conducted separately within the Cobalt project and documented in NK38-REP-03500-0989867 R002 [10]. However, within the review of the TDS HF analysis and review of the EC packages, the Cobalt-60 HF analysis will also be reviewed, and Cobalt team consulted. The Cobalt-60 HFESR is documented in NK38-REP-31935-10010 R000 [11].

Product safety requirements (i.e. those imposed by Health Canada, the Food and Drug Administration, or others) are outside the scope of this program [1].

As per REGDOC 2.5.1 [9], familiarity with established human factors principles, benefits, techniques and guidelines is important to successful implementation of the HFEPP. Therefore, all persons performing the human factors work outlined in this HFEPP will have the appropriate training and qualifications and no additional training will be required.

1.5 TECHNICAL BASIS

The following documents form the technical basis of this HFE program (in order of precedence):

- N-INS-06700-10000 R008, Human Factors Engineering Process [12];
- Canadian Standards Association (CSA) N290.12-14, Human Factors in Design for Nuclear Power Plants [13]
- NUREG-0711 Human Factors Engineering Program Review Model [14]

The following documents inform HFE work planning (in order of precedence):

- CNSC Regulatory Document REGDOC 2.5.1, General Design Considerations: Human Factors [9]
- OPG N-MAN-06700-10001, Human Factors Validation Planning and Methods [15]
- NUREG 0711 Human Factors Engineering Program Review Model [14]

Design guidelines and standards for analytical methods are outlined in Section 3.7 of this HFEPP.

2.0 LEVEL OF EFFORT

In compliance with N-INS-06700-10000 R008, Human Factors Engineering Process [12], N-FORM-10580 ‘Identifying Human Factors Level of Activity’ was completed for MEC 166617 (U3 Target Delivery System). MEC 166617 was screened as “Full” due to the significance of the modification and requires an HFEPP (this document) and HFESR. As described in more detail in Section 3.10, it is assumed that the Human Factors Engineering Verification and Validation Plan (HFVVP) issued for Unit 2 and 4 [16] also applies for Unit 3 therefore an HFVVP is not planned for this work.

3.0 HFE ACTIVITIES

The HFE analysis for this project follows the HFE Program Review Model adapted from NUREG-0711 [14] which describes twelve (12) technical elements. The details of each HFE activity to be carried out within this project are described in the sub-sections that follow. All HFE analyses will be developed in close communication with the design team, (during regular design meetings), relevant analysis teams and independently verified by a second qualified HFE Specialist as was done in the Unit 2 HFEPP [1].

3.1 HFE PROGRAM MANAGEMENT

The development of this HFEPP addresses HFE Program Management. The objectives of this element are to:

1. Prepare a plan which defines the HFE activities to be performed.
2. Identify relevant source documents, and HFE methods and approaches to be utilized to identify Human Factors requirements.
3. Define roles and responsibilities of the HFE design team, and other parts of the team, within the organizations involved.
4. Identify interfaces with other parts of the project, and how these will be handled.

3.2 OPERATING EXPERIENCE (OPEX) REVIEW

The purpose of an Operating Experience Review (OER) is to leverage the practical knowledge from similar applications, or applications with similar/comparable characteristics, to identify risks and opportunities in the implementation of the present design [1].

Since Unit 2 TDS design and implementation was previously completed, the focus of this OPEX review will be on Unit 2/4 OPEX, including:

1. Subject Matter Expert (SME) Discussions: Discussions will be held with OPG personnel from Operations and Maintenance to elicit relevant experience from Unit 2.

2. OPEX Report Review: The DNGS TDS System Tie-In Modification OPEX Report [17] and Unit 4 HFESR OPEX (documented in the Unit 4 interim reports [3] [4]) will be reviewed to identify any HFE relevant issues and keywords to incorporate into Unit 3 OPEX database search (item 3 below).
3. OPG Database Search [18]: OPG Station Condition Records (SCRs) for Unit 2 and an update to HFE keywords used in the Unit 4 HFESR (documented in the Unit 4 interim reports [3] [4]) will be reviewed to identify any HFE relevant OPEX to consider in the Unit 3 design.

Note that a Candu Owners Group (COG) databased search was conducted for Unit 2 and will not be repeated for Unit 3 as the results still apply.

3.3 FUNCTIONAL ANALYSIS (FA) AND ALLOCATION OF FUNCTION (AOF)

An FA was completed for Unit 4[2] as described in the Unit 4 Interim Reports ([3] [4]). Figure 1 shows the high-level system goals, functional units and control functions as documented for Unit 4 [4].

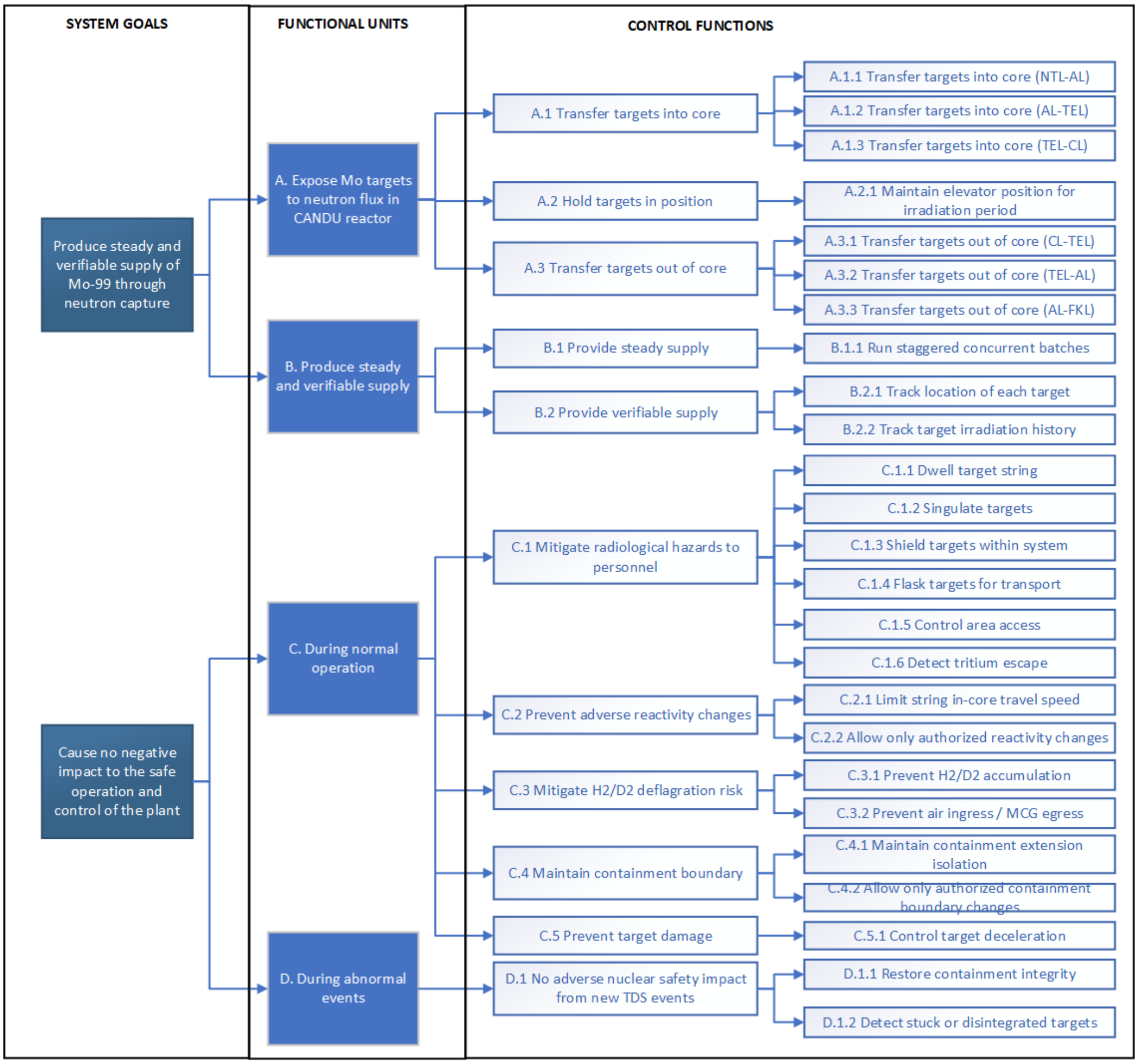

Figure 1: Unit 4 TDS FA (adapted from [4])

The Unit 3 design is not expected to introduce any new functions, alter the functions, or affect the function allocations as described in the HFESR interim reports (see [3] and [4]). The Unit 4 FA will be

[2] The FA completed for Unit 4 also applies to Unit 2. It was completed prior to abandoning work on Unit 4 TDS and focusing on Unit 2. This justification applies anywhere where Unit 4 TDS analysis is referenced.

reviewed to confirm its applicability to Unit 3 including assessing if there is an impact due to any Unit 3 design changes, if any. Although no function changes are anticipated, a function change map will be developed to comprehensively substantiate the claim that there are no changes in functions. Should there be any function changes or function allocation changes identified, the analysis methodology documented in IEC 61839 [19] will be used as a guideline and the applicable sections of the FA will be updated for Unit 3.

3.4 TASK ANALYSIS (TA)

A TA was conducted for the Unit 4 TDS, captured in [4]. The scope of the previously conducted Unit 4 Task Analysis includes:

1. Normal operations, which were analyzed in full to identify error precursors and the potential outcome of human errors during normal operations which constitute the bulk of TDS operating time.
2. Maintenance tasks, consisting of:
    a. Maintenance of existing components belonging to other systems potentially impacted by installation of the TDS (i.e., primarily RRS and SDS1 components on the RMD)
    b. Maintenance of TDS components
3. Abnormal operations, consisting of:
    a. New Initiating Events for TDS
    b. Major alarm responses

Figure 2 shows the Hierarchical Task Decomposition for normal TDS operations. The TA for Unit 4 TDS Normal Operations, Maintenance and Abnormal Conditions can be found in [3] and [4].

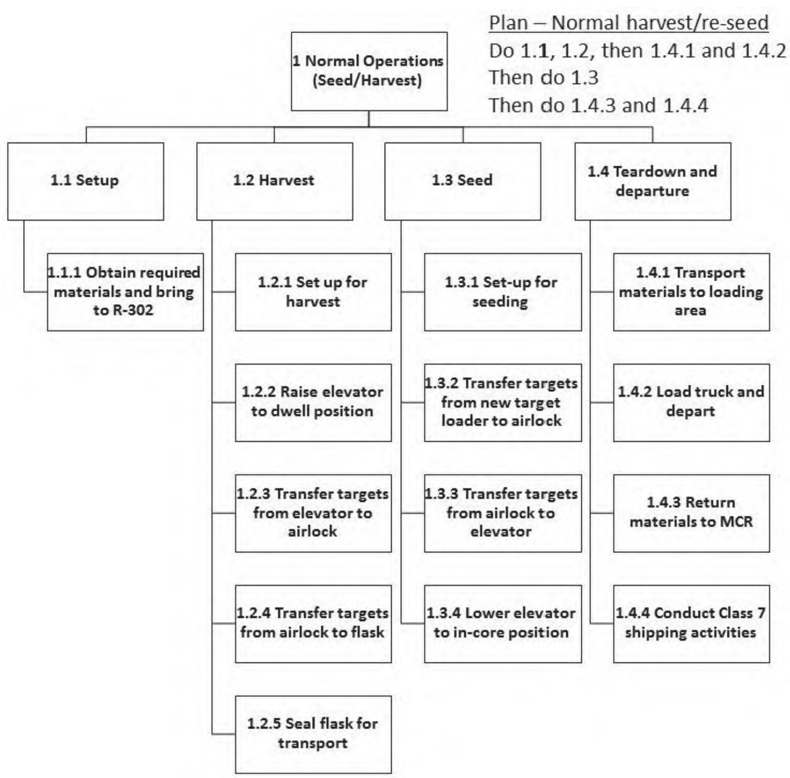

Figure 2: Hierarchical Task Decomposition for TDS Normal Operations [4]

It is anticipated that the tasks in Unit 3 will be the same as in Unit 4, therefore the TA conducted for Unit 4, documented in [3] and [4] will apply to Unit 3. Although no task changes are anticipated, a task change map will be developed to comprehensively substantiate the claim that there are no changes to tasks. Therefore, if there are any design differences identified in Unit 3 that have an impact on tasks, these will be identified in the task change map, and a new TA will be conducted for those tasks only.

Consistent with the approach used for Unit 4, the TA method to be employed is an HTA, coupled with detailed decomposition as described in A Guide to Task Analysis by Kirwan & Ainsworth [20].

If a TA is required, the task decomposition will define the following attributes for each task / step:

- Actor: The person carrying out the task in terms of their work group and/or job title.
- Location: The area of the plant where this action will take place.
- Required Action: The action required by the person to complete the task step, including the Human System Interface (HSI) component/device being acted on.
- Initiating Cue: Information that indicates the task step is required.
- Feedback: The information the operator needs to see to ascertain if the action has been successful.
- Performance Shaping Factors / Error Precursors: Any factors which may increase the probability of human errors which could have an adverse impact on nuclear and/or personnel safety. Cued by the mnemonic TIECH, these factors consist of: (T)ime constraints, (I)nformation requirements, (E)nvironmental factors, (C)ommunication, (C)ompeting tasks, and other sources of (H)uman error.

3.5 STAFFING, QUALIFICATIONS & JOB DESIGN

The staffing model for Unit 3 TDS is assumed to be equivalent to Unit 2, as documented in [5] and shown in Figure 3.

	Role	Responsibility
Normal Duty Crews	ANO*	• Authorize TDS operations • Monitor TDS harvest/seed remotely • Respond to TDS annunciations
	NLO (general)	• Restore TDS containment boundary if impaired • Any other nonstandard operations or alarm responses defined in the NK38-OM-30550 (Sections 5 & 6) [17] which occur while field team is not on shift.
TDS Field Team	NLO (TDS Operator)	• Operate TDS • Fill TDS D_2O reservoir from drums • Add oxygen to DRS for hydrogen/deuterium recombination • Support D_2O sampling
	Advanced Inspection and Maintenance (AIM)	• Flasking including flask and overpack closure and lifting/rigging
	Radiation Protection or personnel with equivalent qualifications	• Perform area surveys • Survey flask • Complete release permits • Decontaminate equipment
Auxiliary / Support Staff	TDS First Line Manager (FLM)	• Plan TDS seeding / harvesting (complete D-FORM-79758 'Target Delivery System - TEL Harvest/Seed Status Form') • Ensure TDS seed / harvest activities included in RMP • Attend RMP Meetings to ensure TDS No Fuel Windows (NFW) are minimally affected
	Chemistry	• Obtain and analyze grab samples including DRS loop gas and D_2O
	Security	• Authorize opening of overhead doors • Inspect outgoing shipments
	BWXT	• Troubleshooting support • Contingency actions (e.g. stuck target recovery) • System maintenance

*ANO may request second ANO to support panel monitoring

Figure 3: Staffing Model for TDS

However, if there are design differences between Unit 2 and Unit 3 and it is determined during the FA and TA that a separate, more detailed staffing and qualification review may be needed, this will be flagged to the project and recommended for inclusion in the project scope.

Per CNSC REGDOC 2.2.5 [21], the Minimum Shift Complement (MSC) defines the minimum number of qualified personnel who are required to be present to ensure the safe continued operation of the DNGS, to respond to all credible postulated Design Basis Accidents (DBA) and to ensure adequate emergency response capability is available for the most resource intensive conditions. The MSC impact on the station was also previously evaluated for Unit 2 and is assumed to apply to the Unit 3 design. As documented in the TDS Unit 2 HFESR [5], introduction of the TDS to Darlington does not impact the MSC technical basis. However, if design changes are introduced in Unit 2 that have a possibility of impacting the MSC (substantiated by the function and task change maps, described in Sections 3.3 and 3.4, respectively), this will be flagged to the project and recommended for inclusion in the project scope.

3.6 TREATMENT OF IMPORTANT HUMAN ACTIONS

Human Actions Important to Safety are identified within probabilistic and deterministic analyses [13]. Probabilistic and deterministic analyses were completed for the TDS Unit 2 design, where it was confirmed that the introduction of the TDS does not impact the credited operator actions included in the models [5]. This analysis is assumed to be applicable to Unit 3 as well, therefore it will not be conducted. However, should there be Unit 3 design differences that may have an impact on credited operator actions, this will be flagged to the project for inclusion in the project scope.

3.7 HUMAN SYSTEM INTERFACE (HSI) DESIGN

For consistency, the goal for the TDS system is for the design to be identical between units, to the extent possible. All Unit 3 TDS design differences from Unit 2, and any differences in layout between Unit 2 and Unit 3 that impact the TDS, will be reviewed by HFE. Where applicable, the following OPG design guidelines will be used during design activities for any design differences between Unit 2 and Unit 3:

- NK38-MAN-06700-10001 HFE Design Engineering Guideline for Main Control Room Panels and Local Control Panels [22]
- NK38-MAN-60310-10001 Annunciation Design Guide [23]
- N-MAN-06700-10000 Human Factors Design Guideline: Maintenance, Inspection and Testing [24]
- N-DG-30100-10003 Human Interface for Engineered Tooling [25]

Where the OPG guidelines do not provide adequate guidance for a specific HSI component, industry design guidelines may also be used. These guidelines may include but will not necessarily be limited to:

- NUREG-0700 Human-System Interface Design Review Guideline [26]
- MIL-STD-1472G Department of Defense Design Criteria Standard Human Engineering [27]

Where OPG HFE guidelines and industry design guidance deviate, trade-offs will need to be made between adhering to established best practices and consistency with existing interfaces. This decision will be made in conjunction with the OPG HFE Specialist assigned to the project. Should any HSIs be replaced (compared to Unit 2) as a result of obsolescence, those components will be assessed by HFE in order to ensure that deltas to form, fit and function are understood and related impacts to HF have been identified, if any.

3.8 PROCEDURE DEVELOPMENT AND TRAINING

Procedure writing and training development will follow established OPG processes and practices. Any procedural updates that are identified as a result of the HFE activities will be forwarded to the Procedures and Training groups and documented in the project Issue Tracking File (ITF). This is in accordance with the requirement for any new technical procedures or a revision to an existing procedure to be initiated through use of a Technical Procedure Action Request [28].

Any training recommendations developed through the HFE analyses resulting from potential design changes and/or OPEX from Unit 2 implementation and operation will be forwarded to the project team and documented in the project ITF.

3.9 PHYSICAL WORK ENVIRONMENT

During review of Unit 3 design, any deltas in the design and unit conditions / layout will be assessed and addressed. For any design differences, the assessment of the physical work environment in which users are performing their tasks will be evaluated as part of the TA; it also forms part of the integrated HSI design work when looking at the overall layout and characteristics of the key work areas.

Consideration will be given to coordinating tasks with other work groups, particularly outage activities that might impact TDS tasks. Where required, physical demands analysis will involve OPG Health and Safety consultation.

3.10 VERIFICATION AND VALIDATION

For the purposes of this HFE Program, Verification and Validation (V&V) are defined as follows [9]:

A. Verification: the process of demonstrating that equipment and system have been designed as specified, and that adherence to human factors guidelines has been maintained.
B. Validation: the process of determining the degree to which the human-machine system design and supporting mechanisms facilitate the achievement of overall safety and operational goals.

The objectives of V&V activities are to determine that the final design conforms to HFE design best practices and enables personnel to successfully perform tasks necessary to achieve operational and safety goals.

V&V activities were previously conducted for Unit 2, as documented in the TDS Unit 2 HFVVP [16], in accordance with CNSC REGDOC 2.5.1 [9], OPG Human Factors Validation Planning and Methods [15] and NUREG-0711 [14]. As Unit 3 is considered a replication of Unit 2, a new HFVVP is not required. Any design changes are expected to be minor in nature and not affect the results of the V&V activities previously conducted. However, if there are task impacts identified, and/or the HSIs are different in Unit 3 than in Unit 2, this may warrant additional validation, including the potential of issuing a new HFVVP. This will be flagged to the project for inclusion into the project scope.

3.10.1 Verification

Unit 2 design will serve as a baseline and verification for only Unit 3 design differences will be carried out using the following evaluation [14]:

- Task-Support Verification (TSV): verification that any new/changed HSIs satisfy the operational information and control requirements identified in the TA. An HFE Specialist will compare the final HSIs against the TA to confirm that all required information and control functionality is available to the user.
- HFE Design Verification (DV): verification that any new/changed HSIs satisfy the operational information and control requirements. First, the HFE Specialist will develop an HSI Inventory and Characterization documenting the information and control requirements identified from the suite of HFE analyses. This is then used as a basis of comparison for the final HSI design as documented in engineering drawings, design reports, etc. The objective of this activity is to ensure that any new/changed HSIs conform to HFE design guidelines and recommendations provided earlier in the program have been incorporated or otherwise adequately resolved.

Additionally, any outstanding items from Unit 2 verification will be reviewed.

3.10.2 Validation

Validation is confirmation that the design as a whole is adequate to accomplish the system goals. At the time of writing this HFEPP, it is assumed that the design differences between Unit 2 and Unit 3 are minor/negligeable and therefore the validation conducted for Unit 2 also applies to Unit 3. The results of the validations are documented in the Unit 2 TDS HFESR [14] and HFESR Addendums [7] [8], and overall, the design was deemed fit-for-purpose/acceptable. As such, there is no additional validation planned for the Unit 3 design.

However, if there are task impacts identified, and/or the HSIs are different in Unit 3 than in Unit 2, this may warrant additional validation, including the potential of issuing a new HFVVP. This will be flagged to the project for inclusion into the project scope. The process would follow the OPG Human Factors Validation Planning and Methods [15].

3.11 DESIGN IMPLEMENTATION

The objective of Design Implementation Review is to ensure that the verified and validated design has been installed and commissioned without significant changes.

Implementation issues from Unit 2 will be incorporated into the scope of review, as applicable. The HFE Specialist will perform as-built verification for Unit 3 and review any Field Initiated Changes (FICs) early in the installation and commissioning process to reduce the impact and risk of work if issues are identified. Unit 3 installation is currently scheduled for February 2026, during outage D2631. HFE will attend the sub-systems Factory Acceptance Testing (FAT) activities and post-installation walkdown(s) to verify the as-built design against the HFE requirements in addition to review of any and any outstanding items in the project ITF.

If in-person walkdowns are not possible, then the use of indirect methods of HFE inspection will be discussed with and accepted by OPG HFE oversight. These methods may include review of AFS information (videos, pictures, AFS checklists, user interviews, etc.) or other alternatives. Any findings from HFE attendance at FAT activities or AFS walkdown(s) will be documented in the HFESR and escalated to the project ITF.

3.12 HUMAN PERFORMANCE MONITORING

Once the design is implemented, on-going human performance monitoring is conducted by OPG. This includes long-term performance monitoring according to N-PROC-RA-0022 R037 – Processing Station Condition Records [29].

4.0 TRACKING AND RESOLUTION OF HFE ISSUES AND RECOMMENDATIONS

HFE Issues and Recommendations identified through the HFE activities in Section 3.0 will be communicated to the design team and tracked by the HFE team. The issues and recommendations will be reviewed regularly during weekly team update meetings and dispositions to these issues/recommendations will be recorded. The full list of issues/recommendations and resolutions to-date will be included in the HFESR. Any issues/recommendations not resolved at the time of issuing the HFESR will be escalated to the project ITF and the project ITF numbers will be documented in the

HFESR. Any open items at the time of issuing the final HFESR will be escalated to the project for resolution and assigned an Action Request (AR).

5.0 DELIVERABLES AND SCHEDULE

At the time of writing this HFEPP, it is expected that two revisions of the HFESR will be provided to document the elements described in the HFEPP; R000 at the end of Detailed Design and R001 after installation.

Table 3 shows the project schedule at the time of issuing this HFEPP. Although the schedule is subject to change, it is not an expectation that the HFEPP will be updated to reflect the updated schedule. It is expected that HFE will be provided sufficient information to conduct an HFE review of each DEC and provide comments to the design team (if any) at least four (4) weeks prior to the completion date for each of the Design ECs listed in the table. This provides the project team an opportunity to disposition all HFE comments prior to the DEC submission date.

Table 3: EC and HFESR Submission Schedule

DEC #	Description	Completion Date
166757	AA Drive Mechanism & Rod Removal for the Moly-99 Project	November 22, 2024
166758	I&C Hardware – Removal of Logic Modules, Cables, and Control Room Mods for TDS	January 14, 2025
166759	TDS Contaminated Exhaust Tie-In	November 14, 2024
166760	TDS Class 3 Power Tie-In	December 20, 2024
166763	TDS OH180 (Instrumentation and Control) Design	December 02, 2024
166766	TDS Cable Tray Design	December 11, 2024
166767	TDS Handrails and Access Gates	November 29, 2024
166768	TDS Lighting	December 02, 2024
166769	TDS End Shield Cooling Expansion Tank and Air System Piping Relocation Modification (R3-302)	January 06, 2025
166770	TDS End Shield Cooling Piping Relocation (R3-301)	November 12, 2024
166771	TDS Mechanical and Civil Design	February 04, 2025
166776	TDS Main Control Room and Control Equipment Room Design	February 19th, 2025

DEC #	Description	Completion Date
All DECs	**HFESR R000**	February 19, 2025[3]
All DECs	**HFESR R001**	December 12, 2026[4]

Final HFESR will not be submitted until all HFE activities / analyses are complete, as the schedule may change and current timing for R001 could be impacted.

Hold points include the following:

1. For each DEC, design verification and task support verification must be completed by the HFE Specialist prior to the DEC submission to OPG.
2. All HFE issues must be resolved or action tracked via the project ITF prior to AFS.

OPG will review HFE analyses conducted by vendors for acceptance.

6.0 HFE TEAM AND PROJECT ORGANIZATION

The following sub-sections describe the organization of the project team including expected communication. It is expected the same roles, responsibilities and communication methods applied during the Unit 2 and 4 HFEPP [1] apply to Unit 3. Therefore, these sections have been taken from the Unit 2 HFEPP and adapted as applicable.

6.1 PROJECT TEAM COMMUNICATIONS

The HFE Specialists will work closely with the designers as an integrated team. Throughout the course of this program, HFE Specialists will provide input to the design by way of meetings, emails, and memos. Formal input by the HFE Specialist will be documented in the HFE deliverables (i.e., the HFESR). For efficiency, HFE input will be raised to the design team as soon as issues / recommendations are identified.

HFE will be included in distribution of project information, document review and comment, and technical reviews. This will help to facilitate timely resolution of HFE issues / recommendations.

6.2 CNSC COMMUNICATIONS

Vendor HFE Specialist on this project will support BWXT in any CNSC communications as requested by BWXT. No regulatory communications are to be held without prior approval from BWXT. BWXT will support OPG in regulatory communications as required in accordance with N-PROC-RA-0047, Communications with the CNSC [30].

6.3 HFE QUALIFICATIONS

All HFE activities will be conducted by qualified HFE Specialists as defined in N-INS-06700-10000 R008, Human Factors Engineering Process [12].

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[3] This date is linked to the end of Detailed Design.
[4] This date is linked to the project AFS.

6.4 PROJECT ROLES AND RESPONSIBILITIES

The team members and key stakeholders for the HFE scope of work are summarized below.

BWXT and Tetra Tech Design Team Leads

- Provide HFE Specialist with current design information as requested
- Receive HFE issues/recommendations and incorporate or otherwise disposition
- Work with the HFE Specialist to resolve HFE issues.
- Inform HFE Specialist if a FIC requires HFE input.

OPG Design Team Lead

- Maintains ultimate responsibility for implementation or disposition of HFE recommendations.

OPG Operations and Maintenance Subject Matter Experts[5]

- Provide input as SMEs for their respective work group.
- Facilitate identification of resources to participate in OPEX interviews, discussions, and HFE validation.

OPG HFE Specialist

- Review HFE deliverables for acceptance.
- Review HSIs for acceptance by OPG.
- Provide general feedback/input as needed.

Tetra Tech HFE Specialists[6]

- Prepare an HFEPP for the project (this document).
- Participate in design meetings and other design activities, and attend all COMS meetings.
- Execute the activities defined in the HFEPP and document in the HFESR. Identify issues and recommendations based on HFE analyses as early as practical in the design process.
- Ensure all HFE issues are resolved or action-tracked before completion of detailed design.
- Work with Tetra Tech and BWXT design teams to integrate HFE requirements and recommendations.
- Ensure HFE activities are integrated into the design schedule.

Cobalt Team (OPG, BWXT, and Tetra Tech)

- Provide HFE Specialist with current design information.
- Review TDS design information to confirm no interference.

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[5] Note that TDS maintenance may be performed by BWXT and not OPG. At the time of issuing this report, negotiations were underway between OPG and BWXT for Unit 2 maintenance. It is expected that Unit 3 would follow the same approach.

[6] At minimum, there will be one HFE Specialist as preparer and one HFE Specialist as verifier.

7.0 REFERENCES

[1] Ontario Power Generation (Kinectrics), NK38-PLAN-30550-00002 R002, Darlington Target Delivery System Human Factors Engineering Program Plan, 2020.

[2] Ontario Power Generation (BWXT), NK38-REP-31710-10002 R001, Project Alpha Irradiation Tooling - Conceptual Design Report, 2018.

[3] Ontario Power Generation (Kinectrics) , NK38-REP-30550-0763175 R000, Darlington Target Delivery System, Human Factors Engineering 40% Detailed Design Report, 2019.

[4] Ontario Power Generation (Kinectrics), NK38-REP-30550-0786795 R000, Darlington Target Delivery System, Human Factors Engineering Detailed Design Interim Report, 2020.

[5] Ontario Power Generation (Kinectrics), NK38-REP-30550-00025 R000, Darlington Target Delivery System Human Factors Engineering Summary Report (HFESR), 2023.

[6] Ontario Power Generation (Kinectrics), NK38-REP-30550-00039 R000, Darlington Target Delivery System, Human Factors Engineering Interim Validation Report, 2022.

[7] Ontario Power Generation (Kinectrics), NK38-REP-30550-00025 ADD-001 R000, Darlington Target Delivery System Human Factors Engineering Summary Report (HFESR) Addendum, 2023.

[8] Ontario Power Generation (Kinetrics), "NK38-REP-30550-00025 ADD-002 R000, Darlington Target Delivery System Human Factors Engineering Summary Report (HFESR) Addendum 002," 2024.

[9] Canadian Nuclear Safety Commission, REGDOC 2.5.1 Version 1.0, General Design Considerations: Human Factors, 2019.

[10] Ontario Power Generation, "NK38-REP-03500-0989867 R002, Cobalt Adjuster and Molybdenum Target Delivery System Interaction," 2023.

[11] Ontario Power Generation (Tetra Tech), NK38-REP-31935-10010 R000, Human Factors Engineering Summary Report – Darlington Cobalt-60 Production Modification, 2024.

[12] Ontario Power Generation, N-INS-06700-10000 R008, Human Factors Engineering Process, 2024.

[13] Canadian Standards Association, N290.12-14, Human Factors in Design for Nuclear Power Plants, 2015.

[14] U.S. Nuclear Regulatory Commission, NUREG-0711 R003, Human Factors Engineering Program Review Model, 2012.

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[17] Ontario Power Generation, NK38-REP-30550-00005 R002, OPEX Report - DNGS Target Delivery System Tie-In Modifications, 2024.

[18] Ontario Power Generation, "N-PROC-RA-0035 R022, Operating Experience Process," 2022.

[19] International Electrotechnical Commission, IEC 61839, Nuclear power plants - Design of control rooms - Functional analysis and assignment, 2000.

[20] B.Kirwan and L.K.Ainsworth, A guide to task analysis, Taylor & Francis Ltd, 1992.

[21] Canadian Nuclear Safety Commission, REGDOC 2.2.5, Minimum Staff Complement, 2019.

[22] Ontario Power Generation , NK38-MAN-06700-10001 R001, HFE Design Engineering Guideline for Main Control Room Panels and Local Control Panels, 2019.

[23] Ontario Power Generation , NK38-MAN-60310-10001 R000, Annunciation Design Guide, 2003.

[24] Ontario Power Generation, N-MAN-06700-10000 R002, Human Factors Design Guideline: Maintenance, Inspection and Testing, 2020.

[25] Ontario Power Generation, N-DG-30100-10003 R000, Human Interface for Engineered Tooling, 1999.

[26] U.S. Nuclear Regulatory Commission, NUREG-0700 R003, Human-System Interface Design Review Guideline, 2020.

[27] Department Of Defense, United States of America , "MIL-STD-1472H Design Criteria Standard Human Factors Engineering," 2020.

[28] Ontario Power Generation, N-PROC-AS-0028 R025, Development, Review and Approval of Technical Procedures, 2024.

[29] Ontario Power Generation, N-PROC-RA-0022 R037, Processing Station Condition Records, 2022.

[30] Ontario Power Generation, N-PROC-RA-0047 R015, Communications with the Canadian Nuclear Safety Commission, 2020.