Nuclear Training Course 224

TIMS Ref. 22004

Chemistry

October 1992

ABSTRACT OF CURRENT REVISION

October 1992 ⇔

Major revision with the following changes to the course.

- Module 224.01, page 16, line 4, added words 'to water' to make clear that the word reduction does not refer to concentration.

- Module 224.02, page 3, objective 2.7 added to reinforce the importance of returning these parameters to specification. The previous text included this description but was not identified as important. The reason why these were action level 3 parameters was not clear.

  Page 13, paragraph 2, addition of three lines describing the problem of sludge deposits and their removal.

  Page 14, second main point of summary, addition of first and third sub-point including two additional adverse affects.

  Pages 23 and 24, text was re-arranged so that the description of action level 3 parameters would follow the introduction. To improve the descriptions of the action level 3 parameters: the first paragraph under dissolved oxygen was added, description of cation conductivity added, sulphate, chloride and sodium were changed to individual descriptions with text for each added.

  Page 25, the text is unchanged but re-arranged to accommodate earlier changes.

  Page 27, added to the description of shutdown concerns, hideout return. For startup, the concern for hideout and concern for maintaining specifications at low power was added.

- Module 224.03, page 9, gadolinium poison description, the words, 'the production of radiolytic D_2', replaces the word 'radiolysis' to make clear the effects of nitrate in the moderator.

- Module 224.04, page 10 & 11, added to the description of consequences of low pH; that solubility changes with pH are a larger factor in pH control than corrosion concerns. Figure 2 added to support the description.

  Page 12, added paragraph 2 to description of consequences of high pH, that carbon steel is not appreciably affected until pH of 13.

ABSTRACT OF PREVIOUS REVISION

October 1991 ⇔	Major rewrite of the course by D.S.Dawson and J.D.Wilkinson.
September 1979 ⇔	Original issue.

NUCLEAR TRAINING COURSE 224

CHEMISTRY

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CHEMISTRY - COURSE 224

INTRODUCTION

1.0 INTENDED AUDIENCE

This course is intended for Authorized Nuclear Operators (ANO) Candidates and Shift Supervisors in Training (SSIT's) who are taking authorization training.

2.0 PREREQUISITES

The prerequisite course for 224 is 424 for operators. M&P candidates may wish to refresh their basic chemistry knowledge by reviewing 424 or PI 24 before studying 224.

3.0 COURSE PURPOSE

This course will review and expand on the chemical theory and examples provided in 424. It will relate these to a more detailed study of the chemical aspects of nuclear plant operation, in regard to both standard and non-standard operating conditions. Although 224 addresses the major chemical factors encountered in a nuclear plant, it is not intended to provide specific plant values which would be found in the operating manuals. However, unless exceptions are noted, any values given are applicable to all Ontario Hydro nuclear stations.

4.0 COURSE GOAL AND EVALUATION STANDARD

At the completion of the course the trainee will demonstrate his or her knowledge by achieving a grade of at least 75% on a final written checkout based on the course objectives. All assignment questions must be satisfactorily completed.

5.0 ASSIGNMENTS

Assignment questions are provided at the end of lessons 2 to 5.

6.0 COURSE OVERVIEW

Lesson 1 provides a review of chemical technology fundamentals as addressed in 424.

Lessons 2 to 5 address the chemistry-related concerns of the following systems:

Lesson 2 The Condensate, Feedwater and Boiler System (C,FW,B)

Lesson 3 The Moderator System

Lesson 4 The Heat Transport System (HTS)

Lesson 5 Two Auxiliary Nuclear Systems
- Liquid Zone Control System
- Irradiated Fuel Bay

7.0 COURSE BOUNDARIES

Lessons 2 to 5 of this course emphasize the chemical properties, concepts, equipment and situations reviewed in Lesson 1. In particular, the effects of water containing various impurities on equipment and systems are noted.

This course deals with the three major water systems in the CANDU system plus two important nuclear-side auxiliary systems. The use of soluble poisons in the moderator to control reactivity is fully explained in other courses. Only the chemical aspects of poisons are examined in this course. Similarly, radioactivity is studied in detail in other courses, so 224 is limited to areas relating to activated corrosion products and radiolysis products.

8.0 CONTROL vs DIAGNOSTIC PARAMETERS

Both **control** and **diagnostic** parameters are discussed throughout this course.

Control Parameters

A **control** parameter is one that is controlled to maintain a given system chemistry. For example, moderator conductivity is controlled using IX columns and in turn controls or limits other parameters. Boiler feedwater pH is controlled by the addition of appropriate chemicals. Control parameters represent the minimum requirements for chemical control of a system.

Action levels are frequently cited with respect to control parameters. An action level identifies a parameter value at which specific action must be taken.

The following is an explanation of the action to be taken at Action Levels 1, 2 and 3, and an example of their application, taken from the NGD chemical specifications manual:

Action Level 1

Return parameter to specification within one week.
If parameter is not within specification within one week, proceed to Action Level 2.

Action Level 2

Return parameter to specification within one day.
If parameter is not within specification within one day, proceed to Action Level 3.

Action Level 3

Shut the unit down within four hours.
Return parameter to specification.

An Action Level 1 condition which becomes Action Level 2 at the expiry of a given time will not become Action Level 3 by virtue of time alone.

The following table provides examples of Action Level specifications. **These numerical values are NOT for examination purposes.**

HEAT TRANSPORT SYSTEM: Main System Control Parameters					
PARAMETER	SPECIFICATION	DESIRED VALUE	ACTION LEVELS		
			1	2	3
pH	10.3 - 10.7	10.3 - 10.5	< 10.3 > 10.7	< 8 > 12	- > 12.5
Dissolved D_2	3-10 cc/kg	7	< 3 > 10	< 1	- -
Chloride	≤ 0.2 mg/kg	ALARA	> 0.2	> 1	> 3
I-131	BNGS-A < 1.5 mCi/kg	ALARA	-	-	≥ 1.5 mCi/kg for ≥ 8 hrs*
	BNGS-B < 1.5 mCi/kg	ALARA	-	-	≥ 1.5 mCi/kg for ≥ 8 hrs*
	DNGS < 2.2 mCi/kg	ALARA	-	-	≥ 2.16 mCi/kg*
	PNGS < 2.7 mCi/kg	ALARA	-	≥ 2.7	≥ 6.4 mCi/kg*
*The action time for I-131 is an exception. The unit should be shut down immediately in a controlled fashion.					

Diagnostic Parameters

A diagnostic parameter is used to troubleshoot a given situation. For example, if moderator conductivity increases, the cause may be identified by observing the system pH or presence of nitrates.

The following tables show another example of the use of diagnostic parameters, taken from the specifications manual.

HEAT TRANSPORT SYSTEM: Main System Diagnostic Parameters		
Lithium and conductivity are measured if the pH goes out of specification. The lithium/pH/conductivity relationships should be monitored for adherence to the theoretical correlation. A low pH can be the result of carbonate in the system, or lithium hideout in the pressurizer. The pH can go above specification if the Li is released from the pressurizer during a shutdown, and then circulated throughout the system upon startup.		
PARAMETER	TYPICAL OPERATING VALUES	TYPICAL CORRECTIVE ACTIONS
Lithium	0.44 - 1.10 mg/kg	Check IX performance. Valve in fresh columns or increase flow as appropriate. Use nonlithiated IX columns to reduce high pH conditions. If low pH exists, check lithium/pH correlation. If Li concentration is within specification, a fresh column should be valved in to remove carbonate. If lithium concentration is also low, LiOH addition may be required.
Conductivity	1.15 - 2.90 mS/m	

HEAT TRANSPORT SYSTEM: Historical Record
The following should be analyzed at a suitable frequency or as a minimum monthly (unless specified differently below) to provide baseline data for trouble shooting and problem solving: Lithium Conductivity Isotopic Tritium Gamma Scan (liquid and crud) Lithium/pH/Conductivity Relationship

9.0 GLOSSARY OF CHEMICAL TERMINOLOGY

The following terms may be referred to in the 224 Chemistry course. It is not required that the glossary be memorized.

ACID	A compound which either contains [H^+] ions or will produce [H^+] ions when dissolved in water.
ACTIVATION	The conversion of a substance into a radioactive substance through neutron bombardment.
ACTIVE	See radioactive.
ADSORPTION	The process of being attracted and adhering to a surface.
AEROBIC	Able to live or grow **only** where free oxygen is present.
ANAEROBIC	Able to live or grow where there is no free oxygen present.
ANEXERS	A common name for ion exchange resins which remove negative ions from solution.
ANION	An ion (having a negative charge) that migrates through the electrolyte toward the anode under a potential gradient.
ANODE	The positive electrode in an electro-chemical cell, where oxidation or corrosion occurs. Metal ions enter solution and electrons flow away from the anode in the external circuit.
BASE	A compound which either contains [OH^-] ions or will produce [OH^-] ions when dissolved in water.
BLOWDOWN	The process of removing water from the lower area of a boiler while allowing its replacement with clean makeup water. This serves to remove dissolved and suspended impurities which accumulate in the boiler water.
CATEXERS	A common name for ion exchange resins which remove positive ions from solution.

CATHODE	The negative electrode in an electro-chemical cell, where reduction occurs. Electrons are released from the cathode to the substance being reduced.
CATHODIC PROTECTION	Preventing corrosion of a component by deliberately making it the cathode in an electrolytic cell.
CATION	An ion (having a positive charge) that migrates through the electrolyte toward the cathode under a potential gradient.
CHEMICAL CONDITIONING	A commissioning process involving appropriate chemical and temperature conditions in order to develop a required surface condition. Example: A protective magnetite layer is produced on the inside surface of the heat transport system carbon steel piping by hot chemical conditioning.
COMPOUND	A substance containing only one type of molecule and at least two elements.
CONDUCTIVITY	The ability to transmit or conduct electric current. (In chemistry this normally refers to WATER in a process system.)
CORROSION	The process of metal wastage or oxidation produced by chemical action.
CORROSION INHIBITOR	A chemical substance which produces a corrosion-resistant layer on the surface of a metal.
COVALENT BOND	A linkage between two atoms produced by sharing electron pair(s) orbiting both atoms.
COVALENT MOLECULE	A molecule in which atoms are bonded together by shared pairs of electrons.
CROSS-LINKING	Bonds forming between individual molecules in a polymer, creating larger molecules.
CRUD	Undissolved solids in a water system, usually on the primary (D_2O) side.

DEDEUTERATION	Recovering D^+, OD^- and D_2O from a spent or saturated ion exchange column resin.
DEUTERIUM	The isotope of hydrogen containing one neutron in the nucleus (symbol D).
D^+	A deuterium ion.
D•	A free radical of deuterium.
D_2O	Heavy water (deuterium oxide).
DEUTERATION	Replacing $[H^+]$, $[OH^-]$ and H_2O in new ion exchange resins with $[D^+]$, $[OD^-]$ and D_2O, in preparation for service in a heavy water system.
ELECTROCHEMICAL CELL	A general term applied to cells of both the galvanic and electrolytic type.
ELECTROLYTE	A liquid containing ions, and thus able to allow electric current to flow through it.
ELECTROLYTIC CELL	A device which uses electric current to produce a chemical reaction.
ELEMENT	A substance consisting of atoms of one type only.
EROSION	The wastage or wearing away of a surface by the abrasive action of moving fluids. Erosion is usually accelerated by solid particles in suspension.
Fe_2O_3	Rust (Hematite) - a porous form of iron oxide.
Fe_3O_4	Magnetite - a relatively impervious form of iron oxide.
FREE RADICAL	A group of atoms containing an unpaired electron. Very reactive.
GALVANIC CELL	A device which employs a chemical reaction to produce an electric current.
H^+	A hydrogen ion.
H•	A free radical of hydrogen.

HETEROGENEOUS	Refers to a mixture containing different components, visually distinguishable from each other.
HOMOGENEOUS	Refers to a substance or solution having the same composition throughout; there is no visible distinction between components.
HOT SOAK	The process of replacing the liquid in a system with hot clean liquid and holding or soaking for a given time.
INVERSE SOLUBILITY	The solubility of the solute in the solvent decreases as the solvent temperature rises.
ION	An atom or molecule possessing a charge.
IONEXER	A common name for a mixed bed ion exchange column.
ISOTOPES	Atoms of the same element which differ only in the number of neutrons they contain.
LITHIATION	Replacement of hydrogen ions with lithium ions in cation exchange resin, prior to service in the HTS purification circuit (done by the manufacturer).
MAGNETITE	A chemical compound (Fe_3O_4) produced on the inner surfaces of the carbon steel piping of the HTS system to protect the metal from corrosion.
MIXED BED	An ion exchange column containing an intimate mixture of anion and cation exchange resins.
MOLAR SOLUTION	A solution containing one gram molecular weight (ie, one mole) of solute per litre of solution.
MOLECULE	The smallest particle of a compound or polyatomic element that can exist in a free state and still retain the characteristics of the element or compound.
MOLECULAR SIEVE	Any of a class of zeolite or similar inorganic polymer having small precisely uniform holes in its crystal lattice that can adsorb molecules not quite small enough to pass through the pores.

NON-VOLATILE	Does not evaporate or vaporize.
OD^-	A deuteroxyl ion (deuteroxide).
•OD	A deuteroxyl free radical.
OH^-	A hydroxyl ion (hydroxide).
•OH	A hydroxyl free radical.
OXIDATION	The loss of electron(s) by an atom or group of atoms.
OXIDATION POTENTIAL	A measure in volts of the tendency of an atom to lose (an) electron(s).
pH	A scale for expressing the acidity or alkalinity of a liquid.
PITTING CORROSION	A form of corrosion commonly associated with deposits or scale creating a barrier between differing concentrations of the hostile substance in the electrolyte. The result is localized corrosion of a metal surface, confined to a small area and taking the form of cavities.
POLAR	Having an uneven distribution of charge.
POLYMER	A substance made up of very large molecules containing recurring units.
PRODUCTS	The substances produced during a chemical reaction.
PURE SUBSTANCE	A substance containing only one type of molecule or atom, ie, a compound or element.
RADICAL	An atom or group of atoms containing an unpaired electron. (Radicals are very reactive.)
RADIOACTIVE	Emitting radiant energy in the form of particles or rays as alpha, beta or gamma rays by unstable atomic nuclei.
RADIOLYSIS	The decomposition of a substance by radiation.
RADIOLYTES	The radiolytic fragments formed when a substance is decomposed by radiolysis.

REACTANTS	The substances being used up during a chemical reaction.
REDUCTION	The gain of electron(s) by an atom or group of atoms.
REGENERATION	Treating a spent ion exchange resin or molecular sieve in such a way that the surface is restored so that it will adsorb impurities again.
SATURATION	The state a surface has reached when it is no longer able to adsorb any more impurities. Commonly referred to as spent or exhausted.
SCALE	Undissolved solids which have plated out onto metal surfaces in a non-active water system.
SILICA	Technically silica is silicon dioxide, SiO_2. In power plants, "silica" refers to the silicon-containing species found in raw water. These include free or "reactive" silica (hydrated silica, $SiO_2 \cdot nH_2O$), and unreactive silicates, particularly of calcium and magnesium. Silica in raw water may be dissolved (mostly reactive) or suspended (mostly silicates).
SOLUBILITY	A measure of the amount of a substance which will dissolve in a given amount of solvent.
SOLUTE	A substance which is dissolved in a solvent.
SOLVENT	The liquid in which a solute is dissolved.
STOICHIOMETRIC	In the correct proportions with respect to the number of each atom found in a given molecule, eg, molecules of D_2 and O_2 (from D_2O) existing in the moderator cover gas in the ratio of 2 to 1.
TRITIUM	The radioactive isotope of hydrogen. It contains two neutrons in its nucleus.
VOLATILE	Evaporates or vaporizes readily.

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