

ICCVAM-Recommended Test Method Protocol
The Human Whole Blood/Interleukin-1 β *In Vitro* Pyrogen Test
Application of Cryopreserved Human Whole Blood

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ICCVAM Final Recommended Protocol for Future Studies Using the Cryopreserved (Cryo) Whole Blood (WB)/Interleukin (IL)-1 β *In Vitro* Pyrogen Test

PREFACE

This protocol is for the detection of Gram-negative endotoxin, a pyrogen, in parenteral drugs, as indicated by the release of IL-1 β from monocytoïd cells in human whole blood (WB) that have been cryopreserved (Cryo). This protocol is based on information obtained from 1) the European Centre for the Validation of Alternative Methods (ECVAM)¹ Cryo WB/IL-1 β Background Review Document (BRD) presented in Appendix A of the Interagency Coordinating Committee on the Validation of Alternative Methods (ICCVAM) BRD (available at http://iccvam.niehs.nih.gov/methods/pyrogen/pyr_brd.htm), and 2) information provided to the National Toxicology Program (NTP) Interagency Center for the Evaluation of Alternative Toxicological Methods (NICEATM) by Dr. Thomas Hartung, Head of ECVAM. The ICCVAM BRD includes the ECVAM Standard Operating Procedure (SOP) for the Cryo WB/IL-1 β test (could be referred to as Monocyte Activation Test), which is based on the Cryo WB/IL-1 β method first described by Schindler et al. (2004). A table of comparison between the ICCVAM recommended protocol and the ECVAM SOP is provided in **Table 1**.

Users should contact the relevant regulatory authority for guidance when using this ICCVAM recommended protocol to demonstrate product specific validation, and any deviations from this protocol should be accompanied by scientifically justified rationale. Future studies using the Cryo WB/IL-1 β pyrogen test may include further characterization of the usefulness or limitations of the assay for regulatory decision-making. Users should be aware that this protocol might be revised based on additional optimization and/or validation studies. ICCVAM recommends that test method users routinely consult the ICCVAM/NICEATM website (<http://iccvam.niehs.nih.gov>) to ensure that the most current protocol is used.

¹ECVAM is a unit of the Institute for Health and Consumer Protection at the European Commission's Joint Research Centre.

Table 1 Comparison of ICCVAM Recommended Protocol with the ECVAM SOP for the Cryo WB/IL-1 β Pyrogen Test

Protocol Component	ICCVAM Protocol	ECVAM Catch-Up Validation SOP ¹
Test Substance	Test neat or in serial dilutions that produce no interference, not to exceed the MVD	Test at MVD
Number of Blood Donors	Minimum of 3 (independent or pooled)	5 (pooled) ²
Decision Criteria for Interference	Mean OD ³ of PPC is 50% to 200% of 0.5 EU/mL EC	Mean OD of PPC is 50% to 200% of 0.5 EU/mL EC
	Not included	Mean OD of PPC \geq 1.6x Mean OD of NPC
Incubation Plate (The number of samples or controls measured in quadruplicate)	NSC (1)	NSC (1)
	EC (5)	EC (2)
	TS (14)	TS (3) x EC (5) spikes = 15 TS
	PPC ⁴ (0)	PPC (3) = 3 TS
	NPC ⁴ (0)	NPC (3) = 3 TS
ELISA Plate	Includes seven point IL-1 β SC and blank in duplicate	Not included
Assay Acceptability Criteria	Mean OD of NSC \leq 0.15	Mean OD of NSC \leq 100 m OD
	Quadratic function of IL-1 β SC $r \geq$ 0.95 ⁵	Not included
	EC SC produces OD values that ascend in a sigmoidal concentration response	Not included
	Not included	Mean OD of 0.5 EU/mL EC \geq 1.6x Mean OD of NSC
	Not included	If one OD of 1.0 EU/mL EC > Max, ELISA may be repeated using reduced incubation time
	Outliers rejected using Dixon's test	Outliers rejected using Dixon's test ⁶
Decision Criteria for Pyrogenicity	Endotoxin concentration TS > ELC ⁷ TS	OD TS > OD 0.5 EU/mL EC ⁶

Abbreviations: Cryo = Cryopreserved; EC = Endotoxin control; ELISA = Enzyme-linked immunosorbent assay; EU = Endotoxin units; IL-1 β = Interleukin-1 β ; MVD = Maximum valid dilution; NPC = Negative product control; NSC = Negative saline control; OD = Optical density; PPC = Positive product control; SC = Standard curve; SOP = Standard operating procedure; TS = Test substance; WB = Whole blood

¹ECVAM Cryo WB/IL-1 β catch-up validation SOP is presented in Appendix A of the ICCVAM BRD (available at http://iccvam.niehs.nih.gov/methods/pyrogen/pyr_brd.htm).

²Samples are collected from five donors and pooled prior to cryopreservation.

³Mean OD values are corrected (i.e., reference filter reading, if applicable, and NSC are subtracted).

⁴In the ICCVAM Cryo WB/IL-1 β protocol, PPC and NPC are assessed in the interference test described in **Section 4.2**, which is performed prior to the ELISA.

⁵Correlation coefficient (r), an estimate of the correlation of x and y values in a series of n measurements.

⁶Included in the ECVAM Trial data report presented in Appendix D of the ICCVAM BRD.

⁷Where unknown, the ELC is calculated (see **Section 12.2**).

1.0 PURPOSE AND APPLICABILITY

The purpose of this protocol is to describe the procedures used to evaluate the presence of Gram-negative endotoxin, a pyrogen, in parenteral drugs. The presence of Gram-negative endotoxin is detected by its ability to induce the release of interleukin (IL)-1 β from monocytoid cells in whole blood (WB) that have been cryopreserved (Cryo). The concentration of IL-1 β released by incubation of Cryo WB cells with a test substance or controls (i.e., positive and negative) is quantified using an enzyme-linked immunosorbent assay (ELISA) that includes monoclonal or polyclonal antibodies specific for IL-1 β . The amount of pyrogen present is determined by comparing the values of endotoxin equivalents produced by Cryo WB cells exposed to the test substance to those exposed to an internationally harmonized Reference Standard Endotoxin (RSE)¹ or an equivalent standard expressed in Endotoxin Units (EU)/mL. A test substance is considered pyrogenic if the endotoxin concentration of the test substance exceeds the Endotoxin Limit Concentration (ELC) for the test substance.

The relevance and reliability of this test method to detect non-endotoxin pyrogens have not been demonstrated in a formal validation study, although data are available in the literature to suggest that this assay has the potential to serve this purpose.

2.0 SAFETY AND OPERATING PRECAUTIONS

All procedures that use human blood-derived materials should follow national/international procedures for handling blood potentially contaminated with pathogens. An example of such guidelines is the Universal Precautions available at <http://www.niehs.nih.gov/odhsb/biosafe/univers.htm>. For non-human blood procedures (e.g., ELISAs), standard laboratory precautions are recommended including the use of laboratory coats, eye protection, and gloves. If necessary, additional precautions required for specific chemicals will be identified in the Material Safety Data Sheet (MSDS).

The stop solution used in the ELISA kit is acidic and corrosive and should be handled with the proper personal protective devices. If this reagent comes into contact with skin or eyes, wash thoroughly with water. Seek medical attention, if necessary.

Tetramethylbenzidine (TMB) solution contains a hydrogen peroxide substrate and 3, 3', 5, 5'-TMB. This reagent is a strong oxidizing agent and a suspected mutagen. Appropriate personal protection should be used to prevent bodily contact.

Bacterial endotoxin is a toxic agent (i.e., can induce sepsis, shock, vascular damage, antigenic response) and should be handled with care. Skin cuts should be covered and appropriate personal protective devices should be worn. In case of contact with endotoxin, immediately flush eyes or skin with water for at least 15 minutes (min). If inhaled, remove the affected individual from the area and provide oxygen and/or artificial respiration as

¹RSEs are internationally harmonized reference standards (e.g., WHO-lipopolysaccharide [LPS] 94/580 *Escherichia coli* [*E. coli*] O113:H10:K-; United States Pharmacopeia [USP] RSE *E. coli* LPS Lot G3E069; USP RSE *E. coli* Lot G; FDA *E. coli* Lot EC6). Equivalent endotoxins include commercially available *E. coli*-derived LPS Control Standard Endotoxin (CSE) or other *E. coli* LPS preparations that have been calibrated with an appropriate RSE.

needed. Skin absorption, ingestion, or inhalation may produce fever, headache, and hypotension.

3.0 MATERIALS, EQUIPMENT, AND SUPPLIES

3.1 Blood Donor Eligibility

Monocytoid cells from WB are the primary source of cytokine production in the Cryo WB/IL-1 β test method as described by Hartung and Wendel (1999) and Schindler et al. (2004, 2006). In the United States (U.S.), the collection of blood and blood components for transfusion and further manufacture (including the use of resulting monocytes in a licensed test) is currently regulated under Section 351 of the Public Health Service (PHS) Act (U.S. Code [U.S.C.], Title 42, Chapter 6A) and/or the Federal Food Drug and Cosmetic Act (U.S.C., Title 21, Chapter 9), both of which require compliance with Current Good Manufacturing Practice (cGMP) regulations (21 CFR Parts 210, 211 and 600-640²).

These regulations and the associated FDA guidance's provide an important resource for information regarding the currently accepted practice for blood manufacture and collection (including donor screening) (<http://www.fda.gov/cber/blood.htm>). Specifically, guidance regarding donor screening questionnaires and links to currently acceptable questionnaires can be found at <http://www.fda.gov/cber/gdlns/donorhistques.htm#iv>. If you have questions regarding the applicability of blood regulations to your specific situation³, it is recommended that you e-mail the Manufacturers Assistance and Technical Training (MATT) Branch established by FDA at matt@cber.fda.gov for advice.

Any participating blood establishment should address how unused components of blood donations will be accounted for and ultimately destroyed, and if the establishment will store the blood preparation, describe the storage procedures to be followed.

3.2 Equipment and Supplies

For all steps in the protocol, excluding the ELISA, the materials that will be in close contact with samples and/or blood cells (e.g., pipet tips, containers, and solutions) should be sterile and pyrogen-free.

3.2.1 Blood Incubation

3.2.1.1 *Equipment*

- Centrifuge

²The requirements for WB can be found at 21 CFR 640.1 *et seq.* In addition, there are specific regulations applicable to red blood cells, platelets, and other blood components. See, for example, 21 CFR 640.10-640.27. Other regulations applicable to the manufacture of blood and blood components include 21 CFR Part 606, the cGMP requirements for blood and blood components, 21 CFR 610.40, the requirements for testing of WB donations, and 21 CFR 640.3, the requirements for determining the suitability of the donor. Blood that enters into U.S. interstate commerce should be tested for antibodies to HIV 1/2, HCV, HTLV I and II, HBc, HBsAg and RPR, WNV and Chagas.

³The collection of blood for research and development purposes or as a component of an *in vitro* test (that is not subject to licensure) may potentially not be required to adhere to the FDA regulations outlined above.

- Hood; Bio-safety, laminar flow (recommended)
- Incubator; cell culture ($37\pm 1^{\circ}\text{C} + 5\% \text{CO}_2$)
- Pipetter; multichannel (8- or 12-channel)
- Pipettors; single-channel adjustable (20 and 200 μL)
- Repeating pipetter
- Vortex mixer

3.2.1.2 *Consumables*

- Centrifuge tubes; polystyrene (15 and 50 mL)
- Combitips; repeating pipetter (1.0 and 2.5 mL)
- Needle set; multify, pyrogen-free, 19 mm, 21 gauge
- Plates; microtiter, 96-well, polystyrene, tissue culture
- Pyrogen-free saline (PFS)
- Reaction tubes; polystyrene (1.5 mL)
- Reservoirs; for fluid collection
- RPMI-1640 cell culture medium
- Tips; pipetter, sterile, pyrogen-free (20 and 200 μL)

3.2.2 ELISA

3.2.2.1 *Equipment*

- Microplate mixer
- Microplate reader (450 nm with an optional reference filter in the range of 600-690 nm⁴)
- Microplate washer (optional)
- Multichannel pipetter

3.2.2.2 *Consumables*

- Container; storage, plastic
- Deionized water; nonsterile
- Plates; microtiter, 96-well, polystyrene
- Pyrogen-free water (PFW)
- Reservoirs; fluid
- Tips; pipetter, nonsterile

⁴The TMB chromagen is measured at OD₄₅₀. However, the use of an IL-1 β ELISA kit with a chromagen other than TMB is acceptable. The ELISA should be measured at a wavelength appropriate for the specific chromagen used.

- Tubes; polystyrene (12mL)

3.2.2.3 ELISA Kit

An ELISA that measures IL-1 β release is used. A variety of IL-1 β ELISA kits are commercially available and the IL-1 β ELISA procedure outlined in this protocol is intended to serve as an example for using an ELISA kit. The IL-1 β ELISA should be calibrated using an international reference standard (e.g., World Health Organization [WHO] 86/680) prior to use. The IL-1 β cytokine assay kits do not provide the RSE or endotoxin equivalent; therefore, this reagent must be purchased separately. Results obtained using these products are subject to the assay acceptability and decision criteria described in **Sections 8.0** and **9.0**. IL-1 β ELISA kit components may include the following:

- ELISA plates coated with anti-human IL-1 β capture antibody; monoclonal or polyclonal
- Buffered wash solution
- Dilution buffer
- Enzyme-labeled detection antibody
- Human IL-1 β reference standard
- PFS
- Stop solution
- TMB⁵/substrate solution

3.3 Chemicals

- Endotoxin (e.g., WHO-lipopolysaccharide [LPS] 94/580 *Escherichia coli* [*E. coli*] O113:H10:K-; United States Pharmacopeia [USP] RSE *E. coli* LPS Lot G3E069; USP RSE *E. coli* Lot G; FDA *E. coli* Lot EC6)

3.4 Solutions

- RPMI-1640 cell culture medium

4.0 ASSAY PREPARATION

All test substances, endotoxin, and endotoxin-spiked solutions should be stored as specified in the manufacturer's instructions. The collection of WB and the procedure for cryopreservation of WB is outlined in **Section 6.1**.

4.1 Endotoxin Standard Curve

An internationally harmonized RSE or equivalent is used to generate the endotoxin standard curve. The use of any other *E. coli* LPS requires calibration against a RSE using the Cryo WB/IL-1 β pyrogen test. A standard endotoxin curve consisting of a Negative Saline Control (NSC) and five RSE concentrations (0.25, 0.50, 1.0, 2.5, and 5.0 EU/mL) are included in the

⁵The use of an IL-1 β ELISA kit with a chromagen other than TMB is acceptable.

incubation step (refer to **Table 4-1**) and then transferred to the ELISA plate. To prepare the endotoxin standard curve, first obtain a 2000 EU/mL stock solution by addition of PFW to the lyophilized content of the stock vial by following the instructions provided by the manufacturer (i.e., 5 mL of PFW is added to a vial containing 10,000 EU). To reconstitute the endotoxin, the stock vial should be vortexed vigorously for at least 30 min or sonicated in a bath sonicator for at least 5 min. Subsequent dilutions should be vortexed vigorously immediately prior to use. The stock solution is stable for not more 14 days when stored at 2 to 8°C or for up to 6 months when kept in a -20°C freezer. An endotoxin standard curve is prepared as described in **Table 4-1** by making serial dilutions of the stock solution in PFS with vigorous vortexing at each dilution step. Dilutions should not be stored, because dilute endotoxin solutions are not as stable as concentrated solutions due to loss of activity by adsorption, in the absence of supporting data to the contrary.

Table 4-1 Preparation of Endotoxin Standard Curve

Stock Endotoxin EU/mL ¹	µL of Stock Endotoxin	µL of PFS	Endotoxin Concentration EU/mL
2000 ^{2,3}	50	1950	50 ⁴
50	100	900	5.0
5.0	500	500	2.5
2.5	400	600	1.0
1.0	500	500	0.50
0.50	500	500	0.25
0	0	1000	0

Abbreviations: EU = Endotoxin units; PFS = Pyrogen-free saline

¹To reconstitute the endotoxin, the stock vial should be vortexed vigorously for at least 30 min or sonicated in a bath sonicator for at least 5 min. Subsequent dilutions should be vortexed vigorously immediately prior to use.

²A 2000 EU/mL stock solution of endotoxin is prepared according to the manufacturer's instructions.

³The stock solution is stable for not more 14 days when stored at 2 to 8°C or for up to 6 months when kept in a -20°C freezer.

⁴This concentration is not used in the assay.

4.2 Interference Test

For every test substance lot, interference testing must be performed to check for interference between the test substance and the cell system and/or ELISA. The purpose of the interference test is to determine whether the test substance (or specific lot of test substance) has an effect on cytokine release.

4.2.1 Interference with the Cell System

All test substances must be labeled as pyrogen-free (i.e., endotoxin levels at an acceptable level prior to release by the manufacturer) to ensure that exogenous levels of endotoxin do not affect the experimental outcome. Liquid test substances should be diluted in PFS. Solid test substances should be prepared as solutions in PFS or, if insoluble in saline, dissolved in dimethyl sulfoxide (DMSO) and then diluted up to 0.5% (v/v) with PFS, provided that this concentration of DMSO does not interfere with the assay. To ensure a valid test, a test substance cannot be diluted beyond its Maximum Valid Dilution (MVD) (refer to **Section 12.3**). The calculation of the MVD is dependent on the ELC for a test substance. The ELC

can be calculated by dividing the threshold human pyrogenic dose by the maximum recommended human dose in a single hour period (see **Section 12.2**) (USP 2007; FDA 1987). Furthermore, test substances should not be tested at concentrations that are cytotoxic to blood cells.

4.2.1.1 *Reference Endotoxin for Spiking Test Substances*

The WHO-LPS 94/580 [*E. coli* O113:H10:K-] or equivalent internationally harmonized RSE is recommended for preparation of the endotoxin-spike solution and the endotoxin standard curve (see **Section 4.1**).

4.2.1.2 *Spiking Test Substances with Endotoxin*

Non-spiked and endotoxin-spiked test substances are prepared in quadruplicate and an *in vitro* pyrogen test is performed. A fixed concentration of the RSE (i.e., 1.0 EU/mL or a concentration equal to or near the middle of the endotoxin standard curve) is added to the undiluted test substance (or in serial two-fold dilutions, not to exceed the MVD). An illustrative example of endotoxin-spiking solutions is shown in **Table 4-2**. For non-spiked solutions, 200 µL of RPMI is added to a well followed by 20 µL of the test substance (i.e., equivalent to the negative product control [NPC]) and 20 µL of Cryo WB (**Section 6.1**). Endotoxin-spiked solutions are prepared by adding 180 µL of RPMI to each well followed by 20 µL of the test substance and 20 µL of Cryo WB. Then, 20 µL of an endotoxin-spike solution (1.0 EU/mL) (i.e., equivalent to the positive product control [PPC]) is added to each well. The contents of the wells are mixed and incubated as outlined in **Section 6.1.5, Steps 6-9**. An ELISA is then performed as outlined in **Section 6.2**, without the IL-1β standard curve.

Table 4-2 Preparation of Endotoxin-Spiked and Non-Spiked Solutions for Determination of Test Substance Interference

Sample Addition	Spiked	Non-spiked
	µL/well ¹	
RPMI	180	200
Endotoxin-spike solution ²	20	0
Test substance (neat and each serial dilution)	20	20
Cryo WB	20	20
Total ³	240	240

Abbreviations: Cryo = Cryopreserved; WB = Whole blood

¹n=4 replicates each

²Endotoxin concentration is 1.0 EU/mL in RPMI.

³A total volume of 240 µL per well is used for the incubation.

The optical density (OD) values of the endotoxin-spiked and non-spiked test substances are calibrated against the endotoxin calibration curve. The resulting EU value of the non-spiked test substance is subtracted from the corresponding EU value of the endotoxin-spiked test substance at each dilution. The spike recovery for each sample dilution is calculated as a percentage by setting the theoretical value (i.e., endotoxin-spike concentration of 1.0 EU/mL) at 100%. For example, consider the following interference test results in **Table 4-3**:

Table 4-3 Example of Interference Data Used to Determine Sample Dilution

Sample Dilution	% Recovery of Endotoxin Control
None	25
1:2	49
1:4	90
1:8	110

If a spike recovery between 50% and 200% is obtained, then no interference of the test substance with either the cell system or the ELISA is demonstrated (i.e., the test substance does not increase or decrease the concentration of IL-1 β relative to the endotoxin spike). The lowest dilution (i.e., highest concentration) of a test substance that yields an endotoxin-spike recovery between 50% and 200% is determined. The test substance is then diluted in serial two-fold dilutions beginning at this dilution, not to exceed the MVD, for use in the assay. Based on the results illustrated in **Table 4-3**, the initial dilution of the test substance would be 1:4 (i.e., the lowest dilution between 50% and 200% of the 1.0 EU/mL EC).

4.2.2 Interference at the MVD

If the data obtained from the experiment in **Section 4.2.1** suggests the presence of interference at the MVD, then consideration should be given for using another validated pyrogen test method.

5.0 CONTROLS

5.1 Benchmark Controls

Benchmark controls may be used to demonstrate that the test method is functioning properly, or to evaluate the relative pyrogenic potential of chemicals (e.g., parenteral pharmaceuticals, medical device eluates) of a specific class or a specific range of responses, or for evaluating the relative pyrogenic potential of a test substance. Appropriate benchmark controls should have the following properties:

- consistent and reliable source(s) for the chemicals (e.g., parenteral pharmaceuticals, medical device eluates)
- structural and functional similarities to the class of substance being tested
- known physical/chemical characteristics
- supporting data on known effects in animal models
- known potency in the range of response

5.2 Endotoxin Control

The EC (i.e., WB incubated with an internationally harmonized RSE) serves as the positive control in each experiment. The results should be compared to historical values to insure that it provides a known level of cytokine release relative to the NSC.

5.3 Negative Saline Control

The NSC (i.e., Cryo WB incubated with PFS instead of the test substance) is included in each experiment in order to detect nonspecific changes in the test system, as well as to provide a baseline for the assay endpoints.

5.4 Solvent Control

Solvent controls are recommended to demonstrate that the solvent is not interfering with the test system when solvents other than PFS are used to dissolve test substances.

6.0 EXPERIMENTAL DESIGN

6.1 Incubation with Test Samples and Measurement of IL-1 β Release

6.1.1 Collection of Human Blood

Human volunteers that have met the donor eligibility criteria described in **Section 3.1** are used as the source of WB. All components of the blood collection system (e.g., syringes, tubes, connecting lines) must be sterile and pyrogen-free. WB is drawn by venipuncture⁶ from the medial cubital or cephalic vein of either the right or left arm and collected in a sterile container that contains anticoagulant solution (e.g., heparin). The total volume of blood collected per donor (i.e., up to 500 mL) will be dictated by experimental design and determined by the test method user. All subsequent handling of WB should be performed in a laminar flow hood using sterile technique to prevent contamination.

6.1.2 Cryopreservation Procedure

The two methods available for cryopreservation of blood are 1) the PEI method developed at the Paul Ehrlich Institute (Langen, Germany) and 2) the Konstanz method developed at the University of Konstanz (Konstanz, Germany).

6.1.3 PEI Method of Cryopreservation

In the PEI method (Schindler et al. 2006), an equal volume of WB from multiple independent donors is pooled⁷ and frozen in a cryoprotective phosphate buffer (Sorensen's) containing 20% (v/v) pyrogen-free, clinical-grade DMSO. The tubes can be stored in a -80°C freezer or in the vapor phase of liquid nitrogen until used.

6.1.3.1 *Konstanz Method of Cryopreservation*

In the Konstanz method (Schindler et al. 2004), pyrogen-free, clinical grade DMSO is added to WB of individual donors at a final concentration of 10% (v/v). An equal volume of WB from multiple independent donors is pooled⁷ and frozen in a computer-controlled freezer using several cycles of programmed freezing down to -120°C. Tubes of WB are then removed from the instrument and stored in the vapor phase of liquid nitrogen until used.

⁶WB is obtained using Universal Precautions (e.g., latex gloves, labcoats, safety glasses) and sterile equipment (e.g., syringes, needles, collection tubes) within a hospital or clinical setting by qualified and adequately trained personnel (i.e., registered nurse, licensed phlebotomist, or medical doctor).

⁷Multiple donors (i.e., a minimum of three) should meet the acceptability criteria as outlined in **Section 8.0** either as a pool of multiple individual donors or as multiple individual donors tested independently.

6.1.3.2 *Thawing Procedure*

The tubes are thawed in an incubator at 37±1°C for 15 min. Prior to use in the assay, the pooled⁷ WB cells should be examined under a microscope to determine that the morphology of the cells is consistent with the appearance of cells that previously yielded acceptable results. The results of this examination should be included in the study report.

6.1.4 Incubation Plate

Test substances should be vortexed vigorously for at least 30 min or sonicated in a bath sonicator for at least 5 min prior to use in the assay. Test substances should be prepared in serial two-fold dilutions beginning at a level of dilution that did not show interference with the test system (see **Section 4.2**) in as many subsequent dilutions that are necessary to be within the linear range of the endotoxin standard curve, not to exceed the MVD. Each incubation plate can accommodate an endotoxin standard curve, a NSC, and 14 test samples (see **Table 6-1**).

Table 6-1 Overview of Incubation Plate Preparation in the Cryo WB/IL-1β Pyrogen Test (PEI Method)

Number of Wells	Sample	RPMI	EC	Test Sample	Cryo WB ¹	Mix the samples; incubate for 10 to 24 hr at 37±1°C in a humidified atmosphere with 5% CO ₂ .	Mix the samples; immediately transfer to an ELISA plate ⁵ and run ELISA or store plate in a -20°C or -80°C freezer.
		μL					
20 ²	EC	180	20	0	40		
4	NSC	180	0	0 ³	40		
56 ⁴	Test samples (1-14)	180	0	20	40		

Abbreviations: Cryo = Cryopreserved; EC = Endotoxin control; IL-1β = Interleukin-1β; NSC = Negative saline control; PEI = Paul Ehrlich Institute; PFS = Pyrogen-free saline; WB = Whole blood

¹For the Konstanz method of cryopreservation, 20 μL of Cryo WB is used and the volume of RPMI is adjusted to 200 μL.

²Five EC concentrations (0.25, 0.50, 1.0, 2.5, 5.0 EU/mL) in quadruplicate

³20 μL of PFS is added instead of the test sample.

⁴14 test samples (n=4) per plate

⁵An IL-1β standard curve is prepared in Columns 11 and 12 on the ELISA plate (see **Table 6-3**). Therefore, 80 wells are available for test samples and controls on the incubation plate.

6.1.5 Incubation Assay for IL-1β Release

Cryo WB is prepared in a microtiter plate using a laminar flow hood (refer to **Section 6.1.1**). All consumables and solutions must be sterile and pyrogen-free. Each plate should be labeled appropriately with a permanent marker. An overview of the incubation plate preparation is shown in **Table 6-1**. The incubation procedure is outlined below:

Step 1. Refer to the incubation plate template presented in **Table 6-2**.

Step 2. Using a pipetter, transfer either 180 or 200 μL of RPMI into each well (for the PEI or Konstanz method of cryopreservation, respectively – refer to **Step 5** below).

Step 3. Transfer 20 µL of test sample or 20 µL of PFS for the NSC into the appropriate wells as indicated in the template.

Step 4. Transfer 20 µL of the EC (standard curve) in quadruplicate into the appropriate wells according to the template.

Step 5. Transfer either 40 or 20 µL of Cryo WB (for the PEI or Konstanz method of cryopreservation, respectively) into each well and mix by gently swirling the plate.

Step 6. Mix the contents of the wells thoroughly by gently pipetting up and down five times using a multichannel pipetter, changing the tips between each row in order to avoid cross-contamination.

Step 7. Place the covered plate in a tissue culture incubator for 10 to 24 hr at 37±1°C in a humidified atmosphere containing 5% CO₂.

Step 8. If using the Konstanz method, freeze the plate in a -20°C or -80°C freezer until the contents of the well are completely frozen and then, thaw the plate at RT or in a water bath not exceeding 37±1°C.

Step 9. Prior to transferring the test samples onto the ELISA plate, mix the contents of the wells by pipetting up and down three times using a multichannel pipetter, changing the tips between each row in order to avoid cross-contamination.

Note: The aliquots may be tested immediately in the ELISA or stored in a -20°C or -80°C freezer for testing at a later time. After transfer to the ELISA plate, freeze the remaining aliquots in a -20°C or -80°C freezer for subsequent experiments, if necessary.

Table 6-2 Incubation Plate - Sample and Control Template

	1	2	3	4	5	6	7	8	9	10	11	12
A	EC ¹ 5.0	EC 5.0	EC 5.0	EC 5.0	TS3	TS3	TS3	TS3	TS11	TS11	Void ³	Void
B	EC 2.5	EC 2.5	EC 2.5	EC 2.5	TS4	TS4	TS4	TS4	TS11	TS11	Void	Void
C	EC 1.0	EC 1.0	EC 1.0	EC 1.0	TS5	TS5	TS5	TS5	TS12	TS12	Void	Void
D	EC 0.50	EC 0.50	EC 0.50	EC 0.50	TS6	TS6	TS6	TS6	TS12	TS12	Void	Void
E	EC 0.25	EC 0.25	EC 0.25	EC 0.25	TS7	TS7	TS7	TS7	TS13	TS13	Void	Void
F	NSC	NSC	NSC	NSC	TS8	TS8	TS8	TS8	TS13	TS13	Void	Void
G	TS1 ²	TS1	TS1	TS1	TS9	TS9	TS9	TS9	TS14	TS14	Void	Void
H	TS2	TS2	TS2	TS2	TS10	TS10	TS10	TS10	TS14	TS14	Void	Void

Abbreviations: EC = Endotoxin control; NSC = Negative saline control; TS = Test substance

¹EC value (e.g., EC 5.0) represents the endotoxin concentration in EU/mL.

²TS number (e.g., TS1) represents an arbitrary sequence for individual test substances.

³Columns 11 and 12 are reserved for the IL-1β standard curve on the ELISA plate (see **Table 6-3**).

6.2 ELISA to Measure IL-1 β Release

6.2.1 IL-1 β Standard Curve

An IL-1 β standard, supplied with the ELISA kit, is used. IL-1 β standards are typically supplied in lyophilized form and should be reconstituted according to the manufacturer's instructions. The stock solution should be diluted in RPMI to the following concentrations: 0, 62.5, 125, 250, 500, 1000, 2000, and 4000 pg/mL. Each well on the ELISA plate will receive 100 μ L of an IL-1 β blank or standard.

6.2.2 ELISA

The manufacturer's instructions provided with the ELISA kit should be followed and a typical experimental design is outlined below. The ELISA should be carried out at RT and therefore all components must be at RT prior to use. Frozen specimens should not be thawed by heating them in a water bath. A suggested ELISA plate template is shown in **Table 6-3**, which includes a five-point EC standard curve, an eight-point IL-1 β standard curve (0 to 4000 pg/mL), and available wells for up to 14 test substances and a NSC each in quadruplicate. The EC standard curve, the NSC, and the test sample supernatants are transferred directly from the incubation plate. The IL-1 β standard curve is prepared as described in **Section 6.2.1**. An overview of the ELISA plate preparation is shown in **Table 6-4**.

Step 1. Add 100 μ L of enzyme-labeled detection antibody to each well.

Step 2. After pipetting up and down three times to mix the supernatant, transfer 100 μ L from each well of the Incubation Plate (A1-10; H1-10) to the ELISA plate.

Step 3. Add 100 μ L of each IL-1 β standard (0 to 4000 pg/mL) into the respective wells on the ELISA plate.

Step 4. Cover the microtiter plate(s) with adhesive film and incubate for 90 min on a microplate mixer at 350-400 rpm at RT.

Step 5. Decant and wash each well three times with 300 μ L Buffered Wash Solution and then rinse three times with deionized water. Place the plates upside down and tap to remove water.

Step 6. Add 200 μ L of TMB/Substrate Solution to each well and incubate at RT in the dark for 15 min. If necessary, decrease the incubation time.

Step 7. Add 50 μ L of Stop Solution to each well.

Step 8. Tap the plate gently after the addition of Stop Solution to aid in mixing.

Step 9. Read the OD₄₅₀ within 15 min of adding the Stop Solution. Measurement with a reference wavelength of 600-690 nm is recommended.⁸

⁸The TMB chromagen is measured at OD₄₅₀. However, the use of an IL-1 β ELISA kit with a chromagen other than TMB is acceptable. The ELISA should be measured at a wavelength appropriate for the specific chromagen used.

Table 6-3 ELISA Plate - Sample and Control Template

	1	2	3	4	5	6	7	8	9	10	11	12
A	EC ¹ 5.0	EC 5.0	EC 5.0	EC 5.0	TS3	TS3	TS3	TS3	TS11	TS11	IL-1 β ³ 0	IL-1 β 0
B	EC 2.5	EC 2.5	EC 2.5	EC 2.5	TS4	TS4	TS4	TS4	TS11	TS11	IL-1 β 62.5	IL-1 β 62.5
C	EC 1.0	EC 1.0	EC 1.0	EC 1.0	TS5	TS5	TS5	TS5	TS12	TS12	IL-1 β 125	IL-1 β 125
D	EC 0.50	EC 0.50	EC 0.50	EC 0.50	TS6	TS6	TS6	TS6	TS12	TS12	IL-1 β 250	IL-1 β 250
E	EC 0.25	EC 0.25	EC 0.25	EC 0.25	TS7	TS7	TS7	TS7	TS13	TS13	IL-1 β 500	IL-1 β 500
F	NSC	NSC	NSC	NSC	TS8	TS8	TS8	TS8	TS13	TS13	IL-1 β 1000	IL-1 β 1000
G	TS1 ²	TS1	TS1	TS1	TS9	TS9	TS9	TS9	TS14	TS14	IL-1 β 2000	IL-1 β 2000
H	TS2	TS2	TS2	TS2	TS10	TS10	TS10	TS10	TS14	TS14	IL-1 β 4000	IL-1 β 4000

Abbreviations: EC = Endotoxin control; NSC = Negative saline control; TS = Test substance

¹EC value (e.g., EC 5.0) represents the endotoxin concentration in EU/mL.

²TS number (e.g., TS1) represents an arbitrary sequence for individual test substances.

³IL-1 β values in columns 11 and 12 are in pg/mL.

Table 6-4 Overview of ELISA Procedure

Enzyme-labeled Antibody (μ L)	Material transfer from Incubation Plate (μ L)	IL-1 β standard (0 to 4000 pg/mL) (μ L)	Incubate 90 min on a plate mixer at 350 to 400 rpm at RT.	Decant and wash each well three times with 300 μ L Buffered Wash Solution and three times with deionized water.	TMB/Substrate Solution (μ L)	Incubate for less than 15 min at RT in dark.	Stop Solution (μ L)	Read each well at OD ₄₅₀ with a 600 to 690 nm reference filter.
100	100	100			200		50	

Abbreviations: OD₄₅₀ = Optical density at 450 nm; RT = Room temperature

7.0 EVALUATION OF TEST RESULTS

7.1 OD Measurements

The OD of each well is obtained by reading the samples in a standard microplate spectrophotometer (i.e., plate reader) using a visible light wavelength of 450 nm (OD₄₅₀) with

a 600 to 690 nm reference filter (recommended)⁹. OD values are used to determine assay acceptability and in the decision criteria for pyrogen detection (see **Sections 8.0** and **9.0**).

8.0 CRITERIA FOR AN ACCEPTABLE TEST

An EC (five-point standard curve) and a NSC should be included in each experiment. An IL-1 β standard curve should be included in each ELISA as shown in the template presented in **Table 6-3**. An assay is considered acceptable only if the following minimum criteria are met:

- The quadratic function of the IL-1 β standard curve produces an $r \geq 0.95$ ¹⁰ and the OD of the blank control is below 0.15.
- The endotoxin standard curve produces OD values that ascend in a sigmoidal concentration response.

An outlying observation that represents either a pool of multiple independent donors or a single individual donor may be excluded if there is confirmation that the accuracy of the medical information provided by an individual donor is suspect, or if the aberrant response is identified using acceptable statistical methodology (e.g., Dixon's test [Dixon 1950; Barnett et al. 1984], Grubbs' test [Barnett et al. 1994; Grubbs 1969; Iglewicz and Houghlin 1993]).

9.0 DATA INTERPRETATION/DECISION CRITERIA

9.1 Decision Criteria for Pyrogen Detection

A test substance is considered pyrogenic when the endotoxin concentration of the test substance exceeds the ELC for the test sample. The ELC can be calculated as shown in **Section 12.2**.

10.0 STUDY REPORT

The test report should include the following information:

Test Substances and Control Substances

- Name of test substance
- Purity and composition of the substance or preparation
- Physicochemical properties (e.g., physical state, water solubility)
- Quality assurance data
- Treatment of the test/control substances prior to testing (e.g., vortexing, sonication, warming, and resuspension solvent)

Justification of the In Vitro Test Method and Protocol Used

Test Method Integrity

⁹The TMB chromagen is measured at OD₄₅₀. However, the use of an IL-1 β ELISA kit with a chromagen other than TMB is acceptable. The ELISA should be measured at a wavelength appropriate for the specific chromagen used.

¹⁰Correlation coefficient (r), an estimate of the correlation of x and y values in a series of n measurements.

- The procedure used to ensure the integrity (i.e., accuracy and reliability) of the test method over time
- If the test method employs proprietary components, documentation on the procedure used to ensure their integrity from “lot-to-lot” and over time
- The procedures that the user may employ to verify the integrity of the proprietary components

Criteria for an Acceptable Test

- Acceptable concurrent positive control ranges based on historical data
- Acceptable negative control data

Test Conditions

- Cell system used
- Calibration information for the spectrophotometer used to read the ELISA
- Details of test procedure
- Description of any modifications of the test procedure
- Reference to historical data of the model
- Description of evaluation criteria used

Results

- Tabulation of data from individual test samples

Description of Other Effects Observed

Discussion of the Results

Conclusion

A Quality Assurance Statement for Good Laboratory Practice (GLP)-Compliant Studies

- This statement should indicate all inspections made during the study and the dates any results were reported to the Study Director. This statement should also confirm that the final report reflects the raw data.

If GLP-compliant studies are performed, then additional reporting requirements provided in the relevant guidelines (e.g., OECD 1998; EPA 2003a, 2003b; FDA 2003) should be followed.

11.0 REFERENCES

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12.0 TERMINOLOGY AND FORMULA

12.1 Assay Sensitivity (λ)¹¹

The variable λ is defined as the labeled sensitivity (in EU/mL) of the LAL Reagent in endpoint assays (e.g., the BET gel-clot technique). For kinetic BET assays, λ is the lowest point used in the endotoxin standard curve.

12.2 Endotoxin Limit Concentration (ELC)^{11,12}

The ELC for parenteral drugs is expressed in Endotoxin Units (EU) per volume (mL) or weight (mg). The ELC is equal to K/M , where:

¹¹From FDA (1987)

¹²From USP (2007)

K is the threshold human pyrogenic dose of endotoxin (EU) per body weight (kg). K is equal to 5.0 EU/kg for intravenous administration. For intrathecal administration, K is equal to 0.2 EU/kg (see also **Section 12.5**).

M is the rabbit test dose or the maximum recommended human dose of product (mL or mg) per body weight (kg) in a single hour period (see also **Section 12.8**).

For example, if a non-intrathecal product were used at an hourly dose of 10 mL per patient, then the ELC would be 0.50 EU/mL.

12.3 Maximum Valid Dilution (MVD)^{11,12}

The MVD is the maximum allowable dilution of a test substance at which the endotoxin limit can be determined. The calculation of the MVD is dependent on the ELC for a test substance. When the ELC is known, the MVD is¹¹:

$$\text{MVD} = (\text{ELC} \times \text{Product Potency [PP]})/\lambda$$

As an example, for Cyclophosphamide Injection, the ELC is 0.17 EU/mg, PP is 20 mg/mL, and the assay sensitivity is 0.065 EU/mL. The calculated MVD would be 1:52.3 or 1:52. The test substance can be diluted no more than 1:52 prior to testing.

If the ELC is not known, the MVD is¹¹:

$$\text{MVD} = \text{PP}/\text{Minimum Valid Concentration (MVC)}$$

$$\text{where, MVC} = (\lambda \times \text{M})/\text{K}$$

where, M is the maximum human dose

As an example, for Cyclophosphamide Injection, the PP is 20 mg/mL, M is 30 mg/kg, and assay sensitivity is 0.065 EU/mL. The calculated MVC is 0.390 mg/mL and the MVD is 1:51.2 or 1:51. The test substance can be diluted no more than 1:51 in the assay prior to testing.

12.4 Negative Product Control (NPC)

For interference testing, the NPC is a test sample to which pyrogen-free saline (PFS) is added. The NPC is the baseline for determination of cytokine release relative to the endotoxin-spiked PPC.

12.5 Parenteral Threshold Pyrogen Dose (K)^{11,12}

The value K is defined as the threshold human pyrogenic dose of endotoxin (EU) per body weight (kg). K is equal to 5.0 EU/kg for parenteral drugs except those administered intrathecally; 0.2 EU/kg for intrathecal drugs.

12.6 Positive Product Control (PPC)

For interference testing, the PPC is a test substance spiked with the control standard endotoxin (i.e., 0.5 EU/mL or an amount of endotoxin equal to that which produces ½ the maximal increase in optical density (OD) from the endotoxin standard curve) to insure that the test system is capable of endotoxin detection in the product as diluted in the assay.

12.7 Product Potency (PP)^{11,12}

The test sample concentration expressed as mg/mL or mL/mL.

12.8 Rabbit Pyrogen Test (RPT) Dose or Maximum Human Dose (M)^{11,12}

The variable M is equal to the rabbit test dose or the maximum recommended human dose of product per kg of body weight in a single hour period. M is expressed in mg/kg or mL/kg and varies with the test substance. For radiopharmaceuticals, M equals the rabbit dose or maximum human dose/kg at the product expiration date or time. Use 70 kg as the weight of the average human when calculating the maximum human dose per kg. If the pediatric dose/kg is higher than the adult dose, then it shall be the dose used in the formula.