INTERNATIONAL MULTIDISCIPLINARY LITHIUM BATTERY TRANSPORT COORDINATION MEETING

SECOND MEETING

Cologne, Germany, 9 to 11 September 2014

REPORT OF THE SECOND MEETING

1. INTRODUCTION

1.1 The second ICAO International Multidisciplinary Lithium Battery Transport Coordination Meeting was hosted by the European Aviation Safety Agency (EASA) and was co-chaired by Mr. Peter Chittenden, EASA and Mr. Richard Hill, Federal Aviation Administration (FAA), Technical Center.

2. PRESENTATIONS

2.1 A series of presentations, grouped by theme as contained in the agenda, were made by the FAA Technical Centre, aircraft manufacturers (Airbus, Boeing) and operators (FedEx), and by representatives of the battery manufacturing industry (NEMA, RECHARGE).

Safety Recommendation

Safety Recommendation Summary (FAA)

The presentation is a compilation of recent safety recommendations made by aircraft accident investigation authorities for the Asiana 747, UPS 747, and UPS DC-8 inflight cargo fire accidents. The recommendations include:

- Reduce the hazards from air transport of lithium batteries and other hazardous materials through improved packaging, quantity limits, location, proximity to other hazmat, detection of undeclared hazmat, training, inspection, supervision, and crew notification
- Require fire suppression systems in all cargo compartments in commercial aircraft
- Require fire detection systems that provide early warning to the flight crew for fires originating inside cargo containers or pallets wrapped with protective covers.

- Require additional design and operational measures to further protect against cargo compartment fires

2.2 *Lithium Metal Battery Risk/Hazards*

Full Scale Lithium Metal Tests (FAA)

The presentation summarizes tests conducted in a Boeing 727 freighter test aircraft to determine the effect of fires involving a large bulk shipment of lithium metal batteries in both the Class E (main deck cargo compartment) and Class C (below floor typical of a passenger airplane) cargo compartments. In the Class E test the fire spread quickly, causing complete smoke obscuration in the cockpit in less than 20 minutes and rising temperatures above the ceiling which contains wiring and control cables. After discontinuing the Class C testing due to high heat and a rapid reduction of halon in the cargo compartment, a severe explosion occurred in the mix bay compartment, which is aft of the cargo compartment, causing extensive damage throughout the aircraft.

Lithium Metal Cells- Risk and Hazard (FAA)

A variety of lithium metal cells have been tested, comprised of various cell chemistries, sizes and configurations. This presentation details the variations of behavior exhibited based on cell chemistry and cell design. A wide range of cell behaviors were exhibited that ranged from innocuous to explosive. In addition, data is presented that showed the results of a lithium metal battery fire in a reduced oxygen environment when inerted with Argon, compared to when inerted with Nitrogen.

2.3 *Lithium ion battery risk Hazards*

Full Scale Lithium-Ion Test and Large Format Cell Tests (FAA)

The presentation summarizes tests conducted in a Boeing 727 freighter test aircraft to determine the effect of fires involving a large bulk shipment of lithium ion batteries in both the Class E (main deck) and Class C (below floor typical of a passenger airplane) cargo compartments. The Class C test demonstrated that, although it did not stop cell-to-cell propagation of thermal runaway, Halon 1301 suppressed the fire involving the electrolyte in the off-gasses from lithium ion cells and the cardboard packaging material. The tests were terminated when the Halon concentration reached 3 percent, the minimum aircraft design concentration.

The tests with large format lithium-ion cells showed similar hazards observed with common lithium ion cells but magnified by the size of the large format cell.

Lithium-Ion Cells- Risk and Hazard (FAA)

A variety of lithium-ion cells have been tested, including various cell chemistries, sizes and configurations. This presentation details the variation of behaviour exhibited based on cell chemistry, and also presents the potential hazard that exists from the build-up of flammable gases from these battery cells in a confined environment i.e. an explosion may occur.

2.4 *Possible Aircraft Risk Mitigation Strategies*

Cargo Fire Suppression (FAA)

The presentation contains videos of tests with the latest technology to safely ship cargo, including fire resistant containers (FRC) and fire containment covers (FCC) for palletized cargo, against fires dominated by a large bulk shipment of lithium batteries. Previous tests have shown that both FRC's and FCC's effectively control and contain fires involving ordinary (non-lithium battery) cargo. However, FRC's and FCC's are ineffective at controlling a lithium metal battery fire, and the fire spread outside each of the devices in less than 20 minutes. The tests also demonstrated that combustible gases emitted by the propagation of lithium ion cells in thermal runaway can collect and cause a gas explosion, even in the presence of a suppression agent in the FRC.

ULD Halon Infiltration Tests (FAA)

Two tests were conducted to determine the rate of Halon 1301 infiltration into a standard LD3 ULD (cargo container). The tests were conducted at two initial Halon 1301 concentrations, and showed that the Halon will penetrate into the LD3, although more work is needed to better understand the factors that determine penetration.

Lithium Battery as Cargo (Airbus)

- Current CS/FAR25 aircraft certification standards do not address changing industry market needs; in particular, cargo compartment fire protection standards have not been designed for the transport of lithium batteries. This finding has been validated further by FAA tests.

- Current ICAO packaging regulations do not take the aircraft limitations in mind.

- The most recent FAA tests suggests that transport of lithium ion batteries represents a similar fire risk to those of lithium metal batteries. Priority should be given on the identified risk for lithium ion batteries based on the significant quantity transported on passenger aircraft.

- Mitigation strategies should meet the industry needs but it is essential to consider limitations associated to airframe systems. These strategies should lead to the safe transport of lithium batteries via air.

- A process must be established to manage future challenges related to the air cargo industry

"Fire Protection - Cargo Compartments" (Boeing, AERO Magazine, 2nd quarter of 2011)

- Cargo compartments are designed to prevent fire and to provide passive and active protection systems should a fire occur.

"Boeing Battery Task Group: Mitigating the Risk of Carrying Lithium Batteries as Cargo", The Seventh Triennial International Fire & Cabin Safety Research Conference, (Philadelphia, 2013)

- An industry forum consisting of airlines, airplane manufacturers, regulatory agencies, battery producers, package manufacturers, shippers, freight forwarders, ULD and equipment manufacturers, and other involved parties is needed to develop an overall solution to reduce risks associated with the transport of lithium batteries.

2.5 *Possible Packaging Risk Mitigation Strategies*

Packaging Presentation (FAA)

Various strategies were tested to prevent or contain lithium battery thermal runaway propagation in lithium cell packaging. The strategies include a fire retardant "over-pack" box, a steel drum, increasing the separation distance between cells, reduced state-of-charge, alternative divider material, and water packets above the cells. Testing demonstrated that by reducing the state of charge of a lithium ion cell to 30%, the propagation of thermal runaway could be greatly reduced or eliminated. A water packet was effective in cooling the cells and preventing thermal runaway propagation. The remaining strategies were largely ineffective in preventing propagation.

Lithium Metal and Lithium-ion Battery Packaging Development (FedEx)

- A "layered" approach works for containing thermal events involving lithium-ion and lithium metal cells and batteries.

- FedEx's Fire Suppression System, both the active foam and the fire containment cover, have been proven to suppress both a fire in which equipment containing lithium-ion batteries were involved and a fire with a limited quantity of small lithium metal batteries.

- The Gel Packs have been proven to stop the spread of a thermal runaway in a bulk shipment of lithium metal or lithium-ion cells.

- Stopping the propagation of thermal runaways provides three benefits:

  - It eliminates the flames or reduces the flames to an intensity level which current techniques will suppress.

  - It assures that any heat generated would not cause damage to surrounding packages; including structural damage to the aircraft.

  - It eliminates the possibility of the flammable gases that are released from reaching an explosive level.

- Development of packaging will be required for each type of battery or battery pack.

Lithium batteries and packing for transport (Recharge)

- Test and modelling of lithium-ion thermal runaway in presence of various cushioning materials were presented: the modelling proposed fits with the experimental results.

- It is shown that the thermal energy released in case of lithium batteries run away is predictable, according to the amount/size of batteries and the environment: lithium-ion batteries have less combustion energy and similar heat release rate compared to several combustible materials.

- Consequently, adapted thermal insulation protecting from propagation of run-away can be calculated, and proposed as good practice reference.

The Safety Level of Lithium Metal Coin Cells (NEMA/Battery Association of Japan)

- Lithium metal coin cells collected worldwide made by manufacturers in other countries showed the same safety level as Japanese coin cells.

- A lithium metal coin cell does not create high temperature by itself, and does not reach thermal runaway by itself.

Packaging Performance Criteria Test (NEMA/Battery Association of Japan)

- Lithium metal coin cells with a lithium content of 0.29g (maximum lithium content of PI 968 Section II) were tested in accordance with "Fire safety packaging performance criteria and test method draft ver.7" protocol.

- Based on test data, lithium metal coin cell did not result in thermal runaway.

Test Data of Lithium ion Cell (NEMA/Battery Association of Japan)

- Lithium ion cells were tested for propagation by using cartridge heater (increasing the temperature to 200°C).

- Based on test data, lithium ion cells with 30% state of charge did not cause or propagate fire but only smoke.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 Problem Statement

Following discussion of all the information contained in the presentations, a problem statement was developed:

A fire involving significant quantities of lithium batteries (UN3090 and UN3480) may exceed the fire suppression capability of the aircraft and could lead to a catastrophic failure of the airframe.

3.2 Developments Since the First Meeting:

3.2.1 The ICAO Council decided to prohibit the carriage of lithium metal batteries on their own (UN3090) as cargo on passenger aircraft. Small quantities may be carried subject to approval (State of Origin and State of the Operator).

3.2.2 An explosion occurred in the two tests to date of lithium-ion cells in “Fire Resistant Containers” (designed to provide protection through oxygen starvation). There is a likelihood that flammable gases, emitted from venting lithium-ion cells, can collect and ignite which could result in an explosion in such containers and possibly in existing ULDs.

3.2.3 The State of Charge (SOC) of a single cell can have a significant effect on reducing propagation of a thermal runaway from cell to cell. Depending upon the chemistry and size, there is a threshold SOC at which the cells have fairly benign propagation characteristics. The meeting agreed to establish this threshold as 30% SOC, on an interim basis, for purposes of its recommendation. Based upon additional testing this threshold may be adjusted for differing chemistries, from factors (e.g. prismatic, cylindrical, etc.) and sizes.

3.2.4 Lithium metal button cells, with a lithium content not exceeding 0.3 grams, may not present a significant hazard and should have a separate UN classification to facilitate shipments.

3.2.5 Results of the tests conducted to date indicate that Class C cargo compartments provide appreciably better protection against the risks associated with a lithium battery fire than other types of cargo compartments.

3.3 Recommended Mitigating Measures:

3.3.1 The Multi-disciplinary Meeting on Lithium Batteries recommend the following mitigating measures be taken to reduce the risk of a fire involving significant quantities of lithium cells/batteries (UN3090 and UN3480) that may exceed the fire suppression capability of the aircraft and could lead to a catastrophic failure of the airframe.

3.3.2 Undeclared and non-compliant shipments of lithium cells/batteries are of significant concern. Recent proposals to develop a safety oversight programme (i.e. ICAO Safety Oversight Audit Programme) in this respect and to establish an awareness campaign for the safe transport of dangerous goods were reviewed by the ICAO Council and the Council requested that the Secretariat take action in implementing this as a matter of priority. The meeting also noted that the United Kingdom has made advancements in identifying large shipments of lithium batteries using x-ray screening technology.

3.3.3 Current provisions allow for the carriage of up to 8 small lithium cells or 2 batteries per package without requirement for complete hazard communication. While this was originally considered as an acceptable approach for individual packages, experience has shown that shippers often overpack packages or shipments may be consolidated which results in significant increase in the number of cells/batteries in a single location. These shipments are not required to be declared to the operator.

3.3.4 Based upon 3.3.3, the meeting made the following recommendations:

3.3.4.1 **Recommendation 1/14 — Excepted Section II Cells/Batteries:**

That current provisions to except Section II cells/batteries continue. However, measures should be taken to prohibit packages of such cells/batteries from being overpacked or consolidated.

3.3.5 In light of the most recent tests and findings, the meeting considered the carriage of lithium-ion batteries in both passenger and cargo aircraft and recommended the following:

3.3.5.1 **Recommendation 2/14 — Performance Based Provision to Limit the Probability of Propagation of Thermal Runway Between Cells:**

That a performance based provision be developed that would limit the probability of propagation of thermal runaway between cells to an acceptable level of risk.

3.3.5.2 **Recommendation 3/14 — State of Charge Level of All Cells:**

That all lithium-ion cells for shipment be limited to a State of Charge of no more than 30% as an interim means to reduce the probability of propagation of thermal runaway between cells.

3.3.5.3 **Recommendation 4/14 (Near-term) — Carriage of Lithium-ion Batteries on Passenger Aircraft:**

Where multiple cargo compartment types are available, that lithium batteries be carried in the cargo compartment with the greatest fire suppression capability.

3.3.5.4 **Recommendation 5/14 (Near-term) — Carriage of Lithium Batteries on Cargo Aircraft:**

That based upon a risk assessment, lithium batteries be carried in the cargo compartment with the most appropriate fire mitigation capability. Alternatively, that shipments of lithium cells/batteries be carried in Class C cargo compartments or in locations where alternative fire suppression is available where feasible and appropriate.

3.3.5.5 **Recommendation 6/14 (Near-term) — Fire Detection and Suppression Agent Accessibility in Class C Compartments:**

That a lithium battery fire be detected rapidly and suppression agent reach the fire rapidly regardless of the use of containers or pallets. This will require a re-assessment of current ULD and fire detection/suppression technologies**.**

3.3.5.6 **Recommendation 7/14 (Near-term) — Use of Enhanced Containers and Fire Containment Covers in Class C Cargo Compartments:**

That, given recent tests, the carriage of lithium-ion batteries in enhanced containers or on pallets fitted with fire containment covers that inhibit the ability of the Class C fire suppression agent from reaching the fire be curtailed, pending further testing.

3.3.5.7 **Recommendation 8/14 — Performance Based Packaging of Lithium Batteries:**

3.3.5.8 That further research and testing be completed as soon as possible on packagings for lithium batteries, that may include the use of cooling agents such as gel packs as a means to add additional protective layers to mitigate the risks associated with the carriage of lithium batteries

3.3.5.9 **Recommendation 9/14 (Long-term) — Equivalent Halon Replacement Extinguishing Agents:**

That any future replacements for Halon 1301 have an equivalent capability or better with respect to lithium battery fires and that consideration be given to amendments to the existing Minimum Performance Specifications (MPS) to take this into consideration.

3.3.5.10 **Recommendation 10/14 (Near-term) — Best Practices in Mitigating the Risks Associated with Carriage of Lithium Batteries:**

That information concerning the best practices for the carriage of lithium batteries be published as soon as practicable, taking into consideration the guidance under development by IATA in this area.

3.3.5.11 **Recommendation 11/14 (Long-term) — Research and Sharing Information Concerning the Management of Risks Associated with the Carriage of Lithium Batteries:**

That States and industry be encouraged to conduct research and share their results in respect of future methods to mitigate the risks associated with the carriage of lithium batteries on aircraft including performance based packaging; use of existing ULDs and any appropriate modifications to these devices; use of fire resistant covers and containers; and enhancements to fire/smoke detection devices.

3.3.5.12 **Recommendation 12/14 (Long-term) — New Aircraft Type Designs:**

That aircraft manufacturers together with regulators consider mitigating strategies for the carriage of lithium batteries in designing new aircraft types.

3.3.5.13 **Recommendation 13/14 — Aircraft Limitations:**

That the Original Equipment Manufacturers characterize the tolerance of their aircraft to temperature, pressure and any other known conditions originating in cargo compartments.

3.3.5.14 **Recommendation 14/14 — Lithium Metal Button Cells:**

That method be established to distinguish lithium metal button cells from other types of lithium metal cells.

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APPENDIX A

LETTER OF INVITATION

Tel.: +1 514 954-6757

Ref.: AN 11/2.12

Mr.
E-mail:

Dear Mr.,

I wish to inform you that the International Civil Aviation Organization (ICAO) will convene the second International Multidisciplinary Lithium Battery Transport Coordination Meeting from 9 to 11 September 2014 in Cologne, Germany. The meeting will be hosted by the European Aviation Safety Agency (EASA).

The purpose of this meeting will be to continue the work from the first International Multidisciplinary Lithium Battery Transport Coordination Meeting, held from 4 to 6 February 2014, in Atlantic City, United States. That meeting developed four recommendations which are included in Attachment A to this letter. The Dangerous Goods Panel (DGP) addressed the first of these recommendations at its working group on lithium batteries meeting (Montréal, 7 to 11 April 2014) by proposing an amendment to the Technical Instructions for the Safe Transport of Dangerous Goods by Air (Doc 9284) forbidding the transport of lithium metal batteries as cargo on passenger aircraft to areas not serviced by cargo aircraft. This amendment was reviewed and approved by the ICAO Air Navigation Commission and Council and will be published in the 2015 2016 Edition of Doc 9284 which becomes applicable on 1 January 2015.

During its review, the Air Navigation Commission raised concerns with the risks all lithium batteries present (i.e. lithium ion and lithium metal) on both passenger and cargo aircraft and supported the development of a performance-based approach to mitigating these risks using the multidisciplinary approach taken in reaching its decision on forbidding lithium metal batteries as cargo on passenger aircraft.

Accordingly, the second International Multidisciplinary Lithium Battery Transport Coordination Meeting will consider risks and potential mitigation strategies related to the transport of lithium batteries by air through input from experts in the fields of dangerous goods, operations and airworthiness and from representatives of the aircraft and battery manufacturing industries.

I am pleased to extend an invitation for you to attend this meeting. If you wish to attend, please confirm by e-mail at fls@icao.int by 15 August 2014.

The meeting will be conducted in English. The terms of reference and the provisional agenda are included in Attachments B and C to this letter. The ICAO focal point will be Mr. Mitch Fox, Chief, Flight Operations Section. Should you require further information, please contact his office by e mail at fls@icao.int.

I wish to thank you for your support and look forward to your active participation in this event.

Yours sincerely,

Nancy J. Graham
Director
Air Navigation Bureau

Enclosures:

A — Recommendations of the First International Multidisciplinary Lithium Battery Transport Coordination Meeting
B — Terms of reference
C — Provisional agenda

ATTACHMENT A

Recommendations of the First International Multidisciplinary Lithium Battery Transport Coordination Meeting

Recommendation 1 — Further restrictions on the carriage of lithium metal batteries in commercial passenger carrying operations

That the carriage of lithium metal batteries as cargo should be further restricted, up to and including a potential ban, on passenger carrying aircraft in commercial air transport. Options for these restrictions should be considered and decided upon by the DGP at its Working Group of the Whole on Lithium Batteries (7 to 11 April 2014) and implemented as soon as possible.

Options include:

Option 1 — Total prohibition on passenger carrying aircraft until such time as the data supporting safe transport is available.

Option 2 — Prohibition with an approval provision (guidance to be provided in the *Supplement to the Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284SU)).

The specific conditions to support an approval process, where the types, quantities and packaging containing lithium metal batteries would not allow a fire from within the package to propagate beyond the packaging or adversely affect flight safety, would be developed for inclusion in the Supplement to the Technical Instructions. Guidance would be developed no later than the next regular amendment to the *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284).

Option 3 — Permission to transport certain limited lithium metal batteries based upon a performance-based criteria for packaging such batteries. Performance-based criteria would be developed for inclusion in the Technical Instructions.

Option 4 — Option 3, plus permission to transport very small cells (e.g. button cells). The number and package configuration would be validated based upon a specification (may or may not be fully declared).

Recommendation 2 — Performance based approach

That a small multidisciplinary cargo safety group be formed to develop a performance-based approach to the conditions of carriage on passenger aircraft using the draft flow chart prepared by the Federal Aviation Administration (FAA) Technical Center (see Appendix F) as the basis for its deliberations.

Recommendation 3 — Cargo aircraft

That risks associated with lithium metal batteries on cargo aircraft be mitigated using the lessons learned in the development of a performance-based approach to controlling the risks associated with the carriage of lithium metal batteries on passenger aircraft, as well as any other potential strategies. A decision on the way forward to be taken during the next DGP working group of the whole meeting in October 2014.

Recommendation 4 — Multidisciplinary approach to cargo safety

That a multidisciplinary approach involving all stakeholders be taken as an essential step to advancing the issue of cargo safety.

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ATTACHMENT B

Terms of Reference
International Multidisciplinary Lithium Battery
Transport Coordination Meeting
9 to 11 September 2014

Goal

At this meeting our primary purpose is to review and discuss the risks/hazards associated with the shipment of lithium metal and lithium ion batteries in both passenger and all cargo (freighter) aircraft cargo compartments. Also, to develop mitigation strategies, as needed, to provide the international aviation community with an acceptable risk for lithium battery shipment and afford the battery industry the least possible burden in implementation and cost.

Organization

The multidisciplinary meeting will be comprised of members from States, International Organizations, and their advisors whose charter is to provide subject matter expertise on aircraft cargo compartment fire safety and the safe shipment of lithium/lithium ion batteries in aircraft.

Objectives

The main objectives are:

- To present data on the risks and hazards of lithium metal/lithium ion batteries.
- To provide information via presentations based on areas of expertise in aircraft fire protection systems and lithium battery packaging, and their effectiveness on mitigating the risks of lithium metal/lithium ion batteries.
- To prioritize the risk/hazard of lithium metal/and lithium ion batteries as it applies to the safety of air transport in passenger and freighter.
- To become the source of knowledge and information on the shipment of lithium/ lithium ion batteries in aircraft cargo compartments.
- To review, discuss and develop, as necessary, mitigation strategies for the safe shipment of lithium metal and lithium ion batteries in aircraft cargo compartments.
- To develop recommendations on the risks and hazards of transporting lithium metal and lithium ion batteries in aircraft cargo compartments and the prioritization of mitigation strategies to minimize the risks and hazards to an acceptable level.
- To submit those recommendations to the relevant panels and the ANC, as appropriate.

Process

Through presentations and discussions, members and advisors at the multidisciplinary meeting will (1) examine and evaluate the risk/hazards of lithium primary and lithium ion batteries related to the safety of air transport, (2) prioritize the risks and (3) develop mitigation strategies for the safe shipment of lithium primary and lithium ion batteries in passenger and freighter aircraft cargo compartments.

Outputs

The meeting will provide the following results:

- Prioritization of the risks and hazards of lithium metal and lithium ion batteries as it applies to the safety of air transport.
- Recommendations for mitigation strategies for the safe shipment of lithium metal and lithium ion batteries in passenger and freighter aircraft cargo compartments.
- Report to all relevant Panels and ANC

References

Annex 6 — *Operation of Aircraft*
Annex 8 — *Airworthiness of Aircraft*
Annex 18 — *The Safe Transport of Dangerous Goods by Air*
Relevant meeting materials

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APPENDIX B

AGENDA

SECOND INTERNATIONAL MULTIDISCIPLINARY LITHIUM BATTERY TRANSPORT COORDINATION MEETING

Cologne, Germany, 9 to 11 September 2014

Day 1 – Tuesday, 9 September 2014	
0900 – 0920	Welcome & introductions
0920 – 0940	Overview of goals & objectives
0940 – 1100	Presentations & videos on lithium metal battery risk/hazards
1100 – 1230	Presentations & videos on lithium Ion battery risk/hazards
1230 – 1400	***Lunch break***
1400 – 1500	Presentations & videos on possible aircraft risk mitigation strategies
1500 – 1600	Presentations & videos on possible packaging risk mitigation strategies
1600 – 1700	Prioritize next two days discussions

Day 2 – Wednesday, 10 September 2014	
0900 – 1230	Review, discuss and develop, as necessary, mitigation strategies for the safe shipment of lithium metal and/or lithium ion batteries in aircraft cargo compartments, based on priority set on day one
1230 – 1400	***Lunch break***
1400 – 1700	Continue morning discussions

Day 3 – Thursday, 11 September 2014	
0900 – 1100	Continue discussions from day two
1100 – 1230	Develop recommendations on the risks and hazards of transporting lithium metal and/or lithium ion batteries in aircraft cargo compartments and the prioritization of mitigation strategies to minimize the risks and hazards to an acceptable level
1230 – 1400	***Lunch break***
1400 – 1600	Continue developing recommendations
1600 – 1700	Discuss way forward

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APPENDIX C

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— END —