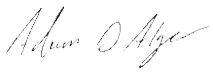
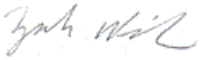
Test Report # 3538 B

Equipment Under Test:	RADIO APPARATUS
Requirements:	FCC Part 1.1307, 2.1091, 2.1093 | ISED Canada RSS-102
Test Date(s):	November 22-24 and December 20, 2021
Prepared for:	Vermeer Manufacturing Company Attn: Ty Gross 1716 Vermeer Rd East Pella, IA 50219

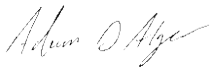
Report Issued by: Adam Alger, Laboratory Manager

Signature:  Date: 8/30/2022

Report Reviewed by: Zach Wilson, EMC Engineer

Signature:  Date: 3/15/2022

Report Constructed by: Adam Alger, Laboratory Manager

Signature:  Date: 3/04/2022

CONTENTS

Laird Connectivity Test Services in Review

The Laird Connectivity LLC laboratory located at W66 N220 Commerce Court Cedarburg, Wisconsin, 53012 USA is recognized through the following organizations:

A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025:2017 with Electrical (EMC) Scope

A2LA Certificate Number: 1255.01

Scope of accreditation includes all test methods listed herein unless otherwise noted

---

Federal Communications Commission (FCC) – USA

Accredited Test Firm Registration Number: 953492

Recognition of two 3 meter Semi-Anechoic Chambers

Government of Canada

Innovation, Science and Economic Development Canada

Accredited U.S. Identification Number: US0218

Recognition of two 3 meter Semi-Anechoic Chambers

1 TEST REPORT SUMMARY

During **November 22-24 and December 20, 2021** the Equipment Under Test (EUT), **RADIO APPARATUS**, as provided by **Vermeer Manufacturing Company** was tested to the following requirements:

Requirement	Description	Specification	Method	Result
FCC Part 1.1307, 2.1091, 2.1093	RF Exposure and equipment authorization requirements	Reported	FCC KDB 447498	Reported
ISED Canada RSS-102	Radiofrequency Radiation Exposure Evaluation: Portable	Reported	RSS-102 Section 2.5.2	Reported

Notice:

The results relate only to the item tested as configured and described in this report. Any additional configurations, modes of operation, or modifications made to the equipment under test after the specified test date(s) are at the decision of the client and may not apply to the data seen in this test report.

The decision rule for Pass / Fail assessment to the specification or standard listed in this test report has been agreed upon by the client and laboratory to be as follows:

Measurement Type	Rule
Emissions – Amplitude	Below specified limit
Emissions – Frequency	1% less than the specification
Immunity	Tested at specified level

2 CLIENT INFORMATION

Company Name	Vermeer Manufacturing Company
Contact Person	Ty Gross
Address	1716 Vermeer Rd East Pella, IA 50219

2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

Product Name	RADIO APPARATUS
Model Number	VERMEER2
Serial Number	Engineering Sample
FCC/ISED ID:	FCC ID: 2AXF5-VERMEER2 IC: 26431-VERMEER2

2.2 Product Description

The Radio Apparatus is a 2.4 GHz Frequency Hopping Spread Spectrum (FHSS) Wireless Module used in OEM Host applications.

2.3 Modifications Incorporated for Compliance

None noted at time of test

2.4 Deviations and Exclusions from Test Specifications

None noted at time of test

2.5 Additional Information

The EUT is a module facilitated using a devkit (model: DVK-RM024-FCC) powered by 5 VDC. The Radio Apparatus houses a proprietary frequency hopping 2.4 GHz radio that operates from 2404 – 2466.9 MHz. Unit tested in the low mid, and high channels as shown below, and in the hopping mode as required for each test. Unit tested with a set of channels comprising 43 channels with 280kHz and 500 kHz data rates.

Low – 2404 MHz
Mid – 2435.5 MHz
High – 2466.9 MHz

2.6 Antenna Information

This EUT was tested with a cabinet radiation method assuming a worst-case antenna gain of 9.0 dBi in accordance with FCC guidance.

Vermeer Part #	Manufacturer	MFG Part #	Type/Description	Gain dBi
296575415	L-COM	HG2409Y-NF	Yagi	9.0
296575413	L-COM	HG2409P-NF	Flat Patch	8.0
296575414	L-COM	HG2408P-NF	Round Patch	8.0
296541293	Pulse / Larsen	SLPT2400NMOHF	Shadow	5.1
296575379	Nearson	S151TC-2450	Dipole	5.0
296541296	Pulse / Larsen	SLPT2400DMN	Shadow	4.8
163722969	Laird	TRA6927M3PB-001	Phantom	4.6
296272382	PCTEL	PCTCN24005	Open Coil Colinear	4.5
296541297	Laird Connectivity	TRAB24003P	Phantom	3.0
296541408	Molex	146153 100mm	Balance Flex	3.0
296589356	Laird Connectivity	TRAB24003NP	Phantom	3.0
296304935	Pulse / Larsen	SPDA172400	Dipole	2.0
296521447	Laird Technologies	MAF94045	PCB Trace	2.0
296541344	Nearson	S181FL-5(178)-PX-2450(S)	Dipole	2.0
296541409	Molex	146153 150mm	Balance Flex	2.0
296575378	Nearson	S181TC-2450	Dipole	2.0
296575416	Nearson	S181FL-6-PX-2450S	Dipole	2.0
296575417	Laird Technologies	001-0014	FlexPIFA	2.0

3 REFERENCES

Publication	Edition	Date	AMD 1
FCC Title 47	-	2022	-
ANSI C63.10	-	2013	-
RSS-247	2	2017	-
RSS-GEN	5	2014	2019
RSS-102	5	3/19/2015	2/2/2021
KDB 447498 D04	V01	11/29/2021	-

4 UNCERTAINTY SUMMARY

Using the guidance of the following publications the calculated measurement uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of k = 2.

References	Version / Date
CISPR 16-4-1	Ed. 2 (2009-02)
CISPR 16-4-2	Ed. 2 (2011-06)
CISPR 32	Ed. 1 (2012-01)
ANSI C63.23	2012
A2LA P103	February 4, 2016
A2LA P103c	August 10, 2015
ETSI TR 100-028	V1.3.1 (2001-03)

Measurement Type	Configuration	Uncertainty ±
Radiated Emissions	Biconical Antenna	5.0 dB
Radiated Emissions	Log Periodic Antenna	5.3 dB
Radiated Emissions	Horn Antenna	4.7 dB
AC Line Conducted Emissions	Artificial Mains Network	3.4 dB
Telecom Conducted Emissions	Asymmetric Artificial Network	4.9 dB
Disturbance Power Emissions	Absorbing Clamp	4.1 dB
Radiated Immunity	3 Volts/meter	2.2 dB
Conducted Immunity	CDN/EM/BCI	2.4/3.5/3.4 dB
EFT Burst/Surge	Peak pulse voltage	164 volts
ESD Immunity	15 kV level	1377 Volts

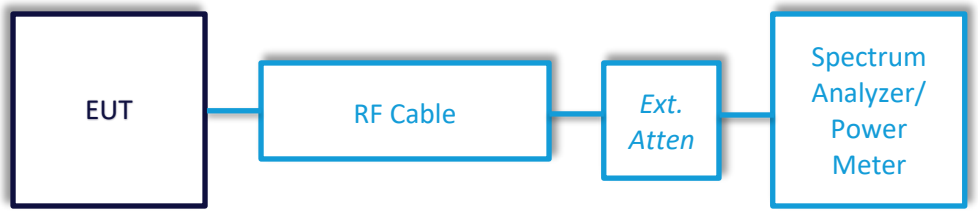
Parameter	ETSI U.C. ±	U.C. ±
Radio Frequency, from F0	$1x10^{-7}$	$0.55x10^{-7}$
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
Supply voltages	3 %	1 %

5 TEST DATA

5.1 Antenna Port Conducted Emissions

Description of Measurement	The direct measurement of emissions at the antenna port of the EUT is achieved by use of a RF connection to a spectrum analyzer or power meter. The cable and attenuator factors are loaded into the analyzer or power meter allowing for direct measurement readings without the need for further corrections.
Example Calculations	Measurement (dBm) + Cable factor (dB) + External Attenuator (dB) = Corrected Reading (dBm) Peak Corrected Reading (dBm) - Duty cycle correction factor (dB) + Ground Reflection factor (dB, if applicable) = Average Corrected Reading (dBm) Margin (dB) = Limit (dBm) – Corrected Reading (dBm)

Block Diagram



5.1.1 Antenna Port Conducted Emissions

Operator	Ivan Alvarez, Anthony Smith, Adam Alger	**QA**	Adam Alger
Temperature	20.2° C	**R.H. %**	22.40
Test Date	11/22,23,24 & 12/20 2021	**Location**	Conducted RF Bench
Requirement	FCC Part 15.247 / RSS-247	**Method**	ANSI C63.10 Sections 6.8, 6.9, 7.8.2, 7.8.3, 7.8.4, 7.8.5, 7.8.6, 7.8.8

Limits:

Maximum Conducted Output Power (mW)	Maximum Conducted Output Power (dBm)
125	21

$$P_{(\mathrm{dBm})} = 10 \cdot \log_{10}(P_{(\mathrm{mW})} / 1\mathrm{mW})$$

Test Parameters

Frequency	30-25000 MHz	**Setup**	EUT connected to Spectrum Analyzer via SMA cable, attenuator, and u.fl to SMA adapter

Instrumentation

Asset #	Description	Manufacturer	Model #	Serial #	Date	Due Date	Status
AA 960143	Cable	Gore	EKD01D01048.0	5546519	2/3/2021	2/3/2022	Active Verification
EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/28/2021	7/28/2022	Active Calibration

EUT Parameters

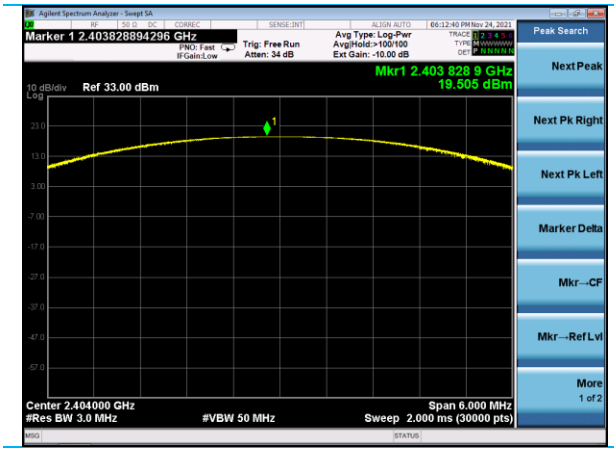
Input Power	5 VDC	**Mode**	Modulated Tx Mode
Frequency	2404 MHz 2435.5 MHz 2466.9 MHz	**Channel**	Low, Mid, High Channel tested.
Notes	EUT tested at both 280 kHz and 500 kHz data rates.		

Data

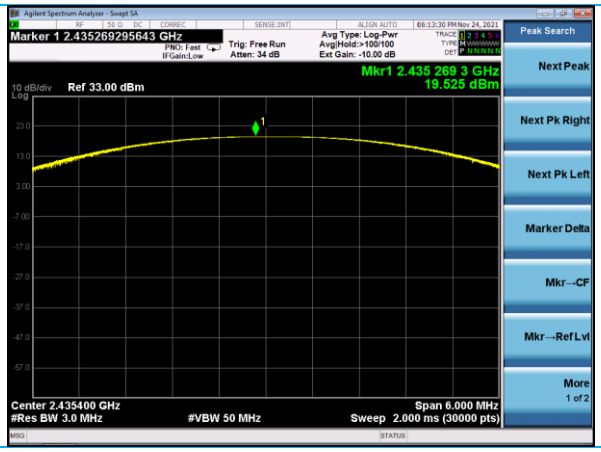
Peak Output Power

Rate	Channel	Frequency (MHz)	Conducted Output Power Level (dBm)	Conducted Output Power Limit(dBm)	Margin (dB)
280	Low	2403.8	19.5	21.0	1.5
280	Mid	2435.3	19.5	21.0	1.5
280	High	2466.9	19.6	21.0	1.4
500	High	2466.9	19.6	21.0	1.4
500	Mid	2435.4	19.5	21.0	1.4
500	Low	2403.9	19.5	21.0	1.5

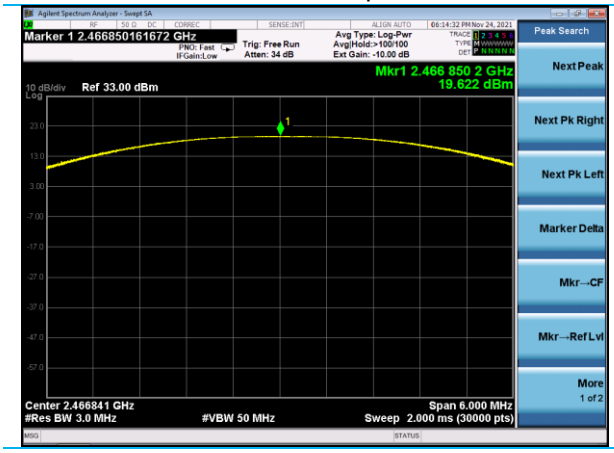
Plots



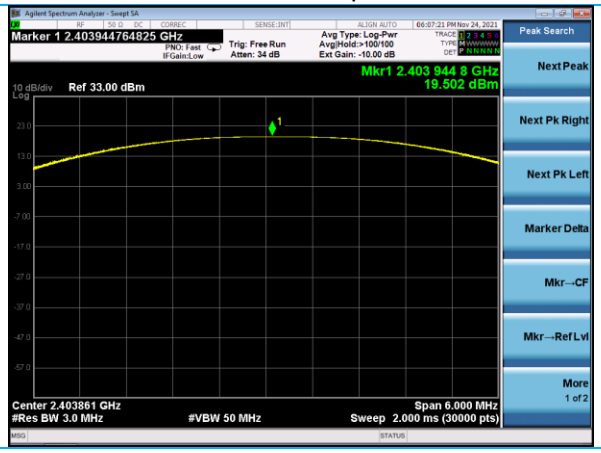
280k Low Ch – Output Power



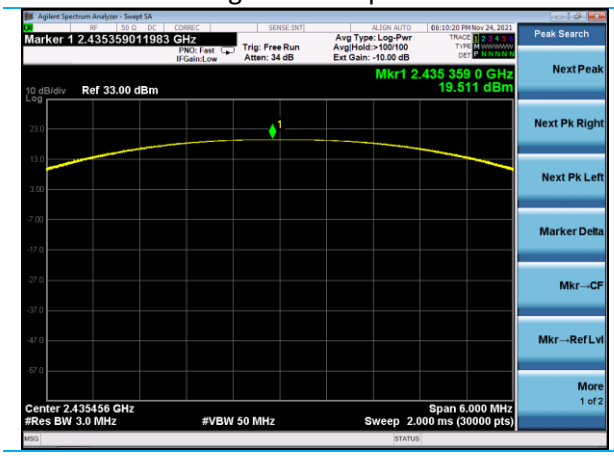
280k Mid Ch – Output Power



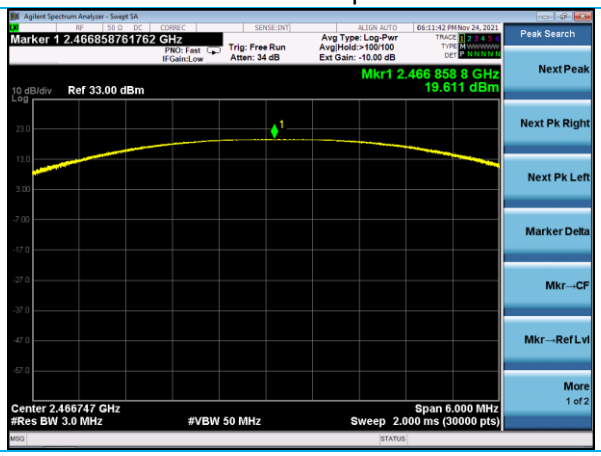
280k High Ch – Output Power



500k Low Ch – Output Power



500k Mid Ch – Output Power



500k High Ch – Output Power

5.2 FCC RF Exposure Calculations

Maximum Conducted Output Power: 19.6 dBm (2466.9 MHz)

Tune-up tolerance: 1 dB

KDB 447498 equations:

$$P_{\text{th}}\,(\text{mW}) = ERP_{20\,\text{cm}}\,(\text{mW}) = \begin{cases} 2040f & 0.3\ \text{GHz} \le f < 1.5\ \text{GHz} \\ 3060 & 1.5\ \text{GHz} \le f \le 6\ \text{GHz} \end{cases} \qquad \text{(B. 1)}$$

$$P_{\text{th}}\,(\text{mW}) = \begin{cases} ERP_{20\,\text{cm}}(d/20\ \text{cm})^{x} & d \le 20\ \text{cm} \\ ERP_{20\,\text{cm}} & 20\ \text{cm} < d \le 40\ \text{cm} \end{cases} \qquad \text{(B. 2)}$$

where

$$x = -\log_{10}\left(\frac{60}{ERP_{20\,\text{cm}}\sqrt{f}}\right)$$

P_{TH} calculation:

ERP(20cm)	d (cm)	cm	f (GHz)	x	mW	dBm
3060	10	20	2.4669	1.903646	818	29.1
3060	9	20	2.4669	1.903646	669	28.3
3060	8	20	2.4669	1.903646	535	27.3
3060	7	20	2.4669	1.903646	415	26.2
3060	6	20	2.4669	1.903646	309	24.9
3060	5	20	2.4669	1.903646	219	23.4
3060	4	20	2.4669	1.903646	143	21.6
3060	3	20	2.4669	1.903646	83	19.2
3060	2	20	2.4669	1.903646	38	15.8
3060	1	20	2.4669	1.903646	10	10.1

Minimum Distance calculated:

Output power + tune-up + gain = EIRP – 2.15 = ERP dBm & mW

Source-base time-averaged output power (mw) = ERP (mw) * duty cycle

Vermeer part #	Manufacturer	MFG Part #	Type / Description	Gain (dBi)	EIRP (dBm)	ERP (dBm)	ERP (mW)	Minimum Distance (cm)
296575415	L-COM	HG2409Y-NF	Yagi	9.0	29.6	27.45	556	9
296575413	L-COM	HG2409P-NF	Flat Patch	8.0	28.6	26.45	442	7
296575414	L-COM	HG2408P-NF	Round Patch	8.0	28.6	26.45	442	7
296541293	Pulse / Larsen	SLPT2400NMOHF	Shadow	5.1	25.7	23.55	226	6
296575379	Nearson	S151TC-2450	Dipole	5.0	25.6	23.45	221	6
296541296	Pulse / Larsen	SLPT2400DMN	Shadow	4.8	25.4	23.25	211	5
163722969	Laird	TRA6927M3PB-001	Phantom	4.6	25.2	23.05	202	5
296272382	PCTEL	PCTCN24005	Open Coil Colinear	4.5	25.1	22.95	197	5
296541297	Laird Connectivity	TRAB24003P	Phantom	3.0	23.6	21.45	140	4
296541408	Molex	146153 100mm	Balance Flex	3.0	23.6	21.45	140	4
296589356	Laird Connectivity	TRAB24003NP	Phantom	3.0	23.6	21.45	140	4
296304935	Pulse / Larsen	SPDA172400	Dipole	2.0	22.6	20.45	111	3
296521447	Laird Technologies	MAF94045	PCB Trace	2.0	22.6	20.45	111	3
296541344	Nearson	S181FL-5(178)-PX-2450	Dipole	2.0	22.6	20.45	111	3
296541409	Molex	146153 150mm	Balance Flex	2.0	22.6	20.45	111	3
296575378	Nearson	S181TC-2450	Dipole	2.0	22.6	20.45	111	3
296575416	Nearson	S181FL-6-PX-2450S	Dipole	2.0	22.6	20.45	111	3
296575417	Laird Technologies	001-0014	FlexPIFA	2.0	22.6	20.45	111	3

When used in a portable configuration the worst-case antenna gain must be used at a minimum distance of 9 cm (90 mm).

5.3 ISED RF Exposure Calculations

Maximum Conducted Output Power: 19.6 dBm (2466.9 MHz)

Tune-up tolerance: 1 dB

Source-base time-averaged output power (mw) = EIRP (mw) * duty cycle

Note: Interpolating between 2450 MHz and 3500 MHz for 2466.9 MHz at 35mm yields 123.016 mW, 52.048 mW at 25mm, 30.032 mW at 20mm, and 15.016 mW at 15mm.

RSS-102 Section 2.5.1:

Table 1: SAR evaluation — Exemption limits for routine evaluation based on frequency and separation distance[4,5]

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of ≤5 mm	At separation distance of 10 mm	At separation distance of 15 mm	At separation distance of 20 mm	At separation distance of 25 mm
≤300	71 mW	101 mW	132 mW	162 mW	193 mW
450	52 mW	70 mW	88 mW	106 mW	123 mW
835	17 mW	30 mW	42 mW	55 mW	67 mW
1900	7 mW	10 mW	18 mW	34 mW	60 mW
2450	4 mW	7 mW	15 mW	30 mW	52 mW
3500	2 mW	6 mW	16 mW	32 mW	55 mW
5800	1 mW	6 mW	15 mW	27 mW	41 mW

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of 30 mm	At separation distance of 35 mm	At separation distance of 40 mm	At separation distance of 45 mm	At separation distance of ≥50 mm
≤300	223 mW	254 mW	284 mW	315 mW	345 mW
450	141 mW	159 mW	177 mW	195 mW	213 mW
835	80 mW	92 mW	105 mW	117 mW	130 mW
1900	99 mW	153 mW	225 mW	316 mW	431 mW
2450	83 mW	123 mW	173 mW	235 mW	309 mW
3500	86 mW	124 mW	170 mW	225 mW	290 mW
5800	56 mW	71 mW	85 mW	97 mW	106 mW

Minimum Separation distance per antenna:

Vermeer part #	Manufacturer	MFG Part #	Type / Description	Gain (dBi)	EIRP (dBm)	EIRP (dBm)	EIRP (mW)	Minimum distance (mm)
296575415	L-COM	HG2409Y-NF	Yagi	9.0	29.6	29.6	912	200
296575413	L-COM	HG2409P-NF	Flat Patch	8.0	28.6	28.6	724	200
296575414	L-COM	HG2408P-NF	Round Patch	8.0	28.6	28.6	724	200
296541293	Pulse / Larsen	SLPT2400NMOHF	Shadow	5.1	25.7	25.7	372	200
296575379	Nearson	S151TC-2450	Dipole	5.0	25.6	25.6	363	200
296541296	Pulse / Larsen	SLPT2400DMN	Shadow	4.8	25.4	25.4	347	200
163722969	Laird	TRA6927M3PB-001	Phantom	4.6	25.2	25.2	331	200
296272382	PCTEL	PCTCN24005	Open Coil Colinear	4.5	25.1	25.1	324	200
296541297	Laird Connectivity	TRAB24003P	Phantom	3.0	23.6	23.6	229	45
296541408	Molex	146153 100mm	Balance Flex	3.0	23.6	23.6	229	45
296589356	Laird Connectivity	TRAB24003NP	Phantom	3.0	23.6	23.6	229	45
296304935	Pulse / Larsen	SPDA172400	Dipole	2.0	22.6	22.6	182	45
296521447	Laird Technologies	MAF94045	PCB Trace	2.0	22.6	22.6	182	45
296541344	Nearson	S181FL-5(178)-PX-2450	Dipole	2.0	22.6	22.6	182	45
296541409	Molex	146153 150mm	Balance Flex	2.0	22.6	22.6	182	45
296575378	Nearson	S181TC-2450	Dipole	2.0	22.6	22.6	182	45
296575416	Nearson	S181FL-6-PX-2450S	Dipole	2.0	22.6	22.6	182	45
296575417	Laird Technologies	001-0014	FlexPIFA	2.0	22.6	22.6	182	45

RSS-102 Section 2.5.1 table 1 exemption limits for routine evaluation based on frequency and separation distance when used at a minimum separation distance of 45 mm for antenna gain equal to and less than 3.0 dBi. Therefore, SAR evaluation is not required.

6 REVISION HISTORY

Version	Date	Notes	Person
0	3/04/2022	Draft	Adam Alger
1	5/20/2022	Final	Adam Alger
2	8/8/2022	TCB Comments	Adam Alger
3	8/30/2022	TCB Comments	Adam Alger

END OF REPORT