Appendix B – CxD ISO/TS 21815-2 testing methodology and acceptance criteria

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The client will supply a CxDI in working order. An authorized person (technology provider representative) will sign-off that the supplied CxDI is in working order as designed. No modifications to any aspect of the CxDI will be allowed once testing has commenced.

The CxD provider must complete the specification spreadsheet to state the capabilities of the device (Appendix A). Different general categories of compliance can be specified for some aspects within the standard, in the protocol or propulsion registers as well as Machine Data these are:

1. Required: The CxD requires this registers to be present on the machine to ensure operation of the device
2. Can Read: The CxD can read this register and may enable additional functionality but does not require this register to be present on the machine to ensure operation
3. Does Not Read: The CxD does not read this register and therefore does not require it for its operation in any form

For capabilities and Set points

1. Available: The CxD has this functionality available and can execute this form of control for example CONTROLLED_STOP=Available, specifies that the CxD can call this command to control the machine.
2. Not Available: The CxD does not have this functionality available.

The testing procedure will evaluate whether the stipulated capabilities are performed according to the published ISO/TS 21815-2:2021 standard**.** The CxD provider will also supply one CxD platform in its entirety and should only require the stipulated connection method. The client will also during testing provide a signed document stipulating the values it read or received by the machine to validate that these values were correctly interpreted.

Test Procedure

Upon receipt of all client supplied items the CxD will be connected to a TMM Emulator which will issue Machine messages and test capabilities. A full trace off all messages between CxD and Machine will be saved for later analysis. The capabilities of the CxD provider will be tested using the following method for each capability.

- **Connector –** The test is to determine whether the correct connector is used and whether data transfer between TMM Emulator and CxD is possible on first connection. Current draw must also be limited to 10A.
    - CxD will pass if correct connector is used with correct wiring and current draw is less than 10A
- **Negotiation –** No specific negotiation sequence is specified. A specific negotiation must be discussed and agreed upon prior to testing. The most basic form of the ISO/TS 21815-2 negotiation will be performed as any other form requiring the passing of keys and other info requires one-on-one development between CxD and machine and is therefore not generic. It will be assumed that if the minimum negotiation can be performed and due to more

complex negotiation requiring direct development between CxD and OEM that testing the basic negotiation sequence is sufficient.
    - CxD will pass if negotiation sequence is completed successfully
    - This is a minimum requirement test
- **Renegotiation –** The test will test whether communication can be re-established after an initially successful connection and negotiation and then a subsequent failure in connection by physically severing the connection.
    - CxD will pass if a successful renegotiation is completed within 1s of restoring the connection
    - This is a minimum specification test
- **Capability enquiry –** The test will determine whether the CxD can successfully determine the capability of the machine. This will be done by initially enabling only a random subset of the possible machine capabilities such as EMERGENCY_STOP, SLOW_DOWN etc. This test will be done by using both the individual enquiry method for each capability on the CxD>>Machine Command messages and the MCAPS propulsion register. The CxD provider will have to sign a document specifying which capabilities were detected for validation. Therefore, the CxD provider must have access to a list of capabilities detected on the machine on the day of testing
    - CxD will pass either method if that method successfully determined the correct machine capabilities. Compliance to each method will be specified separately.
    - This is a minimum specification test and one of the methods needs to pass to meet minimum specification not both.
- **Reading Protocol Registers –** This test evaluates whether the CxD can read protocol registers of the machine. Values will be set inside each of these registers and the CxD provider will have to sign a document stating what values has been read from these registers. Therefore, on the day of testing the CxD proivder must have access to the vales received by the CxD for validation.
    - CxD will pass each type of register if the value the CxD read is correct
    - This test is not a minimum specification test
- **Reading Propulsion Registers –** This test evaluates whether the CxD can read protocol registers of the machine. Not all registers will be tested, rather a single test of each type of register i.e. J1939, Char, ushort16 etc will be tested. Values will be set inside each of these registers and the CxD provider will have to sign a document stating what values have read from these registers for validation. Therefore, on the day of testing the CxD provider must have access to the values received by the CxD for validation.
    - CxD will pass each type of register if the value the CxD read is correct
    - This test is not a minimum specification test
- **Setting Protocol Register –** The test evaluates whether the CxD is capable of setting values inside the protocol registers. The test will be evaluated for every different type of register which has writeable attribute, the standard registers however do not include all types which are writable. The CxD provider will provide a signed document of the values set into these registers.
    - CxD will pass if the values set inside the registers match the provided values
    - This is not a minimum specification test
- **Reset of Registers** – The test evaluates whether the CxD system can correctly issue a reset registers command.
    - CxD will pass if the command is send correctly

    - This is not a minimum specification test
- **Propulsion Commands –** This test evaluates whether the CxD can issue each of the direct action commands such as EMERGENCY_STOP, SLOW_DOWN etc. The CxD will be evaluated whether each of these messages are sent correctly.
    - The CxD will pass each of these commands if the command is sent correctly
    - This is a minimum specification test. The CxD must be capable of slowing down the machine, bringing the machine to a complete stop and keep the machine in a motion inhibited state. Any combination of commands which can accomplish this will be deemed as meeting the minimum requirement.
- **Apply Propulsion Setpoints –** The test evaluates whether the CxD can follow the proper procedure in issuing an apply propulsion setpoint command. The CxD must first be able to set a setpoint, all possible ways can be tested and the CxD must meet one of these criteria. The report will specify which methods CxD can use and which not. The precise value of the setpoint must be provided by the CxD provider in a signed document. The CxD must afterwards load propulsion setpoints. All possible methods will be tested (SELECT, MATCH_TAG, APPLY_FROM_LIST, etc.) The CxD must be able to perform at least one of these methods to pass. The CxD will be tested if the setpoints are tested for validity by performing a APPLY_PROPULSION_SETPOINTS_CONFIRM command, this is not required by the standard but will be stipulated in the report if this is performed or not. The CxD will afterwards issue the command to apply the propulsion setpoints
    - CxD – will pass if the correct procedure is followed and each aspect is completed successfully.
    - This will form part of the minimum specification if it is the only way the CxD uses to bring the machine to a complete stop
- **Machine Data -**This test evaluates whether the CxD receives and correctly interprets the machine data. Specific values of will be sent to the CxD and a document must be signed stipulating the values of the received messages.
    - The CxD will pass if the values received by the CxD corresponds to that send by the TMM Emulator. All values will be tested whether they pass i.e. Gear position, direction of motion, speed, roll and pitch etc.
    - Certain measurements form part of the minimum specification. The CxD must be able to correctly read the following data sent by the TMM Emulator:
        - Direction of motion
        - Gear position
        - Payload status
        - All faults
    - If the CxD uses the following data in any way, the CxD must be able to correctly read the following data send by the TMM Emulator:
        - Speed
        - Motion inhibit status
        - Override status
    - Other measurements that are included in the ISO standard but is not a minimum requirement are:
        - Rollback status
        - Traction status
        - Pitch
        - Roll

- **Error Handling –** The test evaluates the error handling of the CxD. In the event that an incorrect message is provided the CxD is tested on whether the CxD resends the command until any timeout is reached after which a new renegotiation step is performed
- **Incorrect Message Frequency –** The CxD will be tested to evaluate whether replying to command messages at different frequencies affect the operation of the CxD. Since precise timing on CxD is an issue this test just validates the robustness of the CAN implementation. The reply delay will be set from a slow connection of 100ms per message to 10ms.
    - CxD will pass if the reply delay does not affect the performance of the system
    - This is a minimum specification test.
- **Correct Message ID -**The CxD is evaluated on whether the Message ID from both the CxD>>MachineStatus and -Command Message IDs are unique for new messages. Any missing or repeated IDs will be flagged. i.e. the message ID should increment and rollover while being unique.
    - CxD will pass if no error flags are set
    - Reserved SPN values must not be used (0xFA, 0xFE, 0xFF)
    - This is a minimum specification test
- **Connection Stability –** The stability of the connection will be tested throughout testing and any connection issues such as delays in communication or dropping of connection will be noted
    - CxD will pass if connection is stable without significant drops, a single drop of connection will not result in failure, however if the connection is deemed to be too unstable the CxD will not pass
    - CxD will pass if any connection dropouts are detected within 500ms and are infrequent during testing
    - This is a minimum specification test

Reasons for not Passing a Test

The TMM will be deemed to fail a test if one of the following criteria is met

- Improper procedure is followed
- Loss of communication occurs during normal operations
- Incorrect values are read or set or sent
- Test is not completed i.e. the desired outcome is not achieved

Supplied in testing report

The report from the testing process will provide a detailed list of capabilities which the CxD successfully performs. The test report will indicate whether the CxD meets the minimum requirement also a list of aspects which are recommended but not a requirement