



Designation: F3243 – 21

Standard Practice for Implementing Communications Impairments on A-UGV Systems¹

This standard is issued under the fixed designation F3243; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice considers impairments of communications within an automatic, automated, or autonomous unmanned ground vehicle (A-UGV) system during task execution. An A-UGV system typically uses communications between an A-UGV and fixed system components and resources, such as off-board control, job and fleet scheduling, infrastructure equipment interactions, or cloud-computing programs for tasks. Communications impairments can cause an A-UGV operation to change in various ways that can include delays or failure to complete the task.

1.2 This practice is designed for applying known communications impairments to an A-UGV system in conjunction with A-UGV task testing. It is designed to create similar changes in communications that can possibly cause task performance limiting effects that are often experienced by an A-UGV system in different environments.

1.3 This practice is intended to simulate impairments that may be present during the operation of an A-UGV system. This practice can be used, for example, by a manufacturer to indicate that system performance was tested to be robust against specific test communications impairments. The tests are not intended to test situations that should be eliminated during system installation, for example, a duplicate internet protocol (IP) address on the network.

1.4 This practice only describes communications impairments. It does not specify an A-UGV task. The A-UGV task should be a defined ASTM International test method or task description in similar detail.

1.5 This practice defines methods to record communications impairment types and extents while the A-UGV is stationary or performs a task. Temporal or spatial extents in which communications impairments occur include the timing, duration, location within the task, or other triggered events. Examples for implementing common communications impairments are provided.

¹ This practice is under the jurisdiction of ASTM Committee F45 on Driverless Automatic Guided Industrial Vehicles and is the direct responsibility of Subcommittee F45.04 on Communication and Integration.

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1.6 This practice is not intended for:

1.6.1 Communications impairments between onboard components of an A-UGV, for example, onboard sensors-to-onboard computers.

1.6.2 Communications or measurement impairments directly affecting external reference or positioning systems, for example, global positioning system (GPS) used for navigation and range/azimuth sensor-to-wall reflectors.

1.7 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use. Safety standards for A-UGVs (for example, ITSDF B56.5, ISO 3691-4) should be followed.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

[F3200 Terminology for Driverless Automatic Guided Industrial Vehicles](#)

[F3218 Practice for Documenting Environmental Conditions for Utilization with A-UGV Test Methods](#)

[F3244 Test Method for Navigation: Defined Area](#)

[F3265 Test Method for Grid-Video Obstacle Measurement](#)

[F3327 Practice for Recording the A-UGV Test Configuration](#)

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

2.2 Other Standards:

ANSI/ITSDF B56.5 Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles³

ISO 3691-4 Industrial trucks — Safety requirements and verification — Part 4: Driverless industrial trucks and their systems⁴

3. Terminology

3.1 Many terms used within this standard are defined as in Terminology F3200. The following terms and definitions are used within this standard and are not defined within Terminology F3200.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 communications impairment, *n*—specified change in the communications that can include changes in connectivity state, latency, data rate, and/or data integrity between the A-UGV and other equipment that is part of the A-UGV system.

4. Significance and Use

4.1 A-UGVs operate in a wide range of indoor and outdoor applications that include many communications challenges that can affect A-UGV control and monitoring. An A-UGV system or A-UGVS as defined in Terminology F3200 includes the A-UGV and all associated components, equipment, software, and communications necessary to make a fully functional

system. Communications impairments can cause: (1) changes in A-UGV operation, (2) changes in behavior in system components such as control and scheduling, or (3) changes in operation or timing of infrastructure equipment coordination. This practice is intended to record the task performance of an A-UGV while communications are impaired in a specified and repeatable manner (for example, standard test method).

4.2 Communications impairments can occur at a variety of locations within the A-UGVS. The network topology in Fig. 1 shows many of the common communications links that could be impaired. The numbered arrows in Fig. 1 label different places where communications impairments could occur. The box colors (that is, green, red, blue) indicate different types of impairments where the two red boxes are similar to each other. Fig. 1 will be used throughout this practice and included on the test report for use in describing the test setup and results by the test supervisor.

4.3 The requested expected results provide pass/fail reporting criteria along with recorded notes pertinent to the test or results or both. It is possible that the communications impairments used will have no noticeable effect, and this is often the desired outcome.

5. Summary of Practice

5.1 This section provides an outline of the practice describing the essential features of the procedures. Two types of tests are summarized: (1) stationary test and (2) task tests (baseline and impaired communication) where the task is a repeatable representative or actual real-world A-UGV task. Impairments and expected results are then outlined.

5.2 Tests:

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁴ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

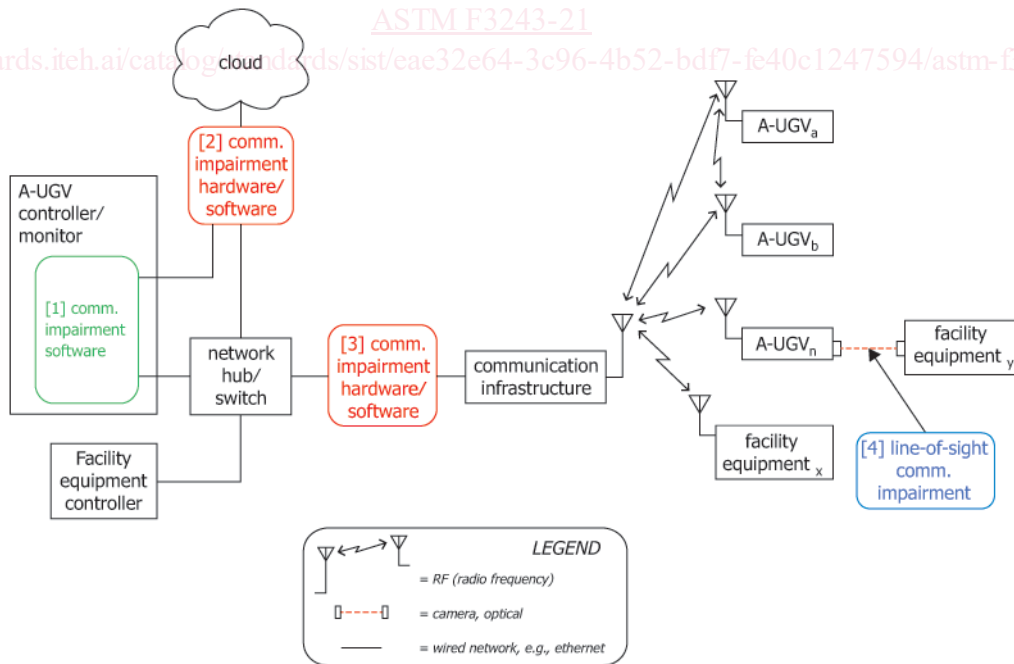


FIG. 1 Block Diagram of Communications for Control/Monitoring of A-UGVs and Associated Facility Equipment in which Numbers with Arrows Indicate Examples of Communications Impairment Locations

5.2.1 *Stationary Test*—A stationary test is recommended to ensure expected A-UGV operation prior without potentially unsafe A-UGV motion caused by communications impairments. It requires that the A-UGV remain stationary while in an active state. This test method is described in Sections 7 through 11.

5.2.2 *Standard ASTM Test Method Test*—ASTM A-UGV test methods clearly define tasks on which this practice can be applied including, for example: navigation tasks (Test Method F3244), docking tasks⁵, and stopping in response to an obstacle introduced within the A-UGV stop zone (Test Method F3265).

5.3 *Baseline and Impairment Implementation:*

5.3.1 *Baseline*—Establishing a baseline by completing the task with no communications impairments will determine if the task is expected to succeed under nominal communications conditions. Care should be taken to ensure consistent configuration of the A-UGV between tests.

5.3.2 *Impairment Implementation*—A repeatable communications impairment method will be used for the test repetitions. Controlling over-the-air radio frequency (RF) communications impairments in an accurate and repeatable way can be difficult, hard to calibrate, and expensive. Traffic control software can be used to implement communications impairments of A-UGVS data in a wired segment of the network topology. Different configurations of the traffic control software can be used to create repeatable communications impairments similar to impairments typical of wireless and wired communications (see example in Appendix X1).

5.4 *Impairment Types*—Many impairments can be implemented with wired connections and traffic control software. Basic impairment types include:

5.4.1 *Interruption of Communications for a Limited Time*—Communication, wireless and wired, can stop for many reasons, including interference, loss of signal strength, network traffic, and equipment failure. There are two things that typically happen when communications are interrupted: the data may be queued and sent later when the connection resumes or the data sent during the interruption may be lost. Either condition may occur based on the A-UGV system network hardware and protocols.

5.4.1.1 Use traffic control software in a wired, Ethernet, or other similar system connection method in which throughput of information can be computer controlled to simulate communications interruptions.

5.4.1.2 Alternatively, a wired communications link may be disconnected for a specified duration to create a communications interruption.

5.4.1.3 Other types of communications can be interrupted, for example, a near-field optical link with the A-UGV may be blocked by using an opaque material to interrupt communication in one or both directions.

5.4.2 *Lossy Communications that Discard a Fraction of the Ongoing Communications Traffic*—Partial communications impairment is also evident in wireless. This can similarly be simulated using a computer controlled, wired method.

⁵ Test Method for Docking A-UGVs is an unpublished ASTM standard in development.

5.4.3 *Rate Limited Communication*—Wireless communications technologies typically reduce bitrate with weakening signal strength. Increasing distance between the transmitter and receiver, as happens when an A-UGV moves around, is the simplest example of a cause of a weakening signal. In the testing environment, traffic control software can mimic these types of rate limitations in a more repeatable manner without using hard-to-control and potentially unknown RF conditions.

5.4.4 *Communications Latency*—Wireless technologies can become saturated or use multi-hop strategies and cause communications delays. Wired communications to servers, especially offsite (“in the cloud”), can cause communications delays. Computer-controlled wired methods can simulate communications latency in a repeatable way.

5.5 *Impairment Extents*—The extents of the communications impairment(s), including some, or all, of:

5.5.1 *Time-Based Impairment*—All start, end times, or durations, or both, for each impairment;

5.5.2 *Location-Based Impairment*—Locations of the A-UGV within the test apparatus for the start/end of each impairment; and

5.5.3 *Quantify each Impairment*—The amount of the impairment(s), for example, amount of latency introduced, bit rate limitations, or data loss percentage.

5.6 *Impairment Combinations*—Test impairments can be introduced individually, sequentially, or in combination.

6. Apparatus

6.1 Additional apparatus is required beyond the A-UGVS that can repeatably provide controlled communications impairments. The test apparatus for controlling communications impairments should be easily fabricated to facilitate self-evaluation by A-UGV manufacturers, installers, and users. An example is shown in Appendix X1.

NOTE 1—It is suggested to consult the A-UGVS manufacturer before implementing communications impairments as incorrectly applied impairments (for example, antenna removal) may cause damage to A-UGVS components.

6.2 The communications impairments apparatus is intended to be constructed with one or more of the following scenarios:

6.2.1 Traffic control software to impair communications programmatically,

6.2.2 Unplugged cabled communication, and

6.2.3 Blocked optical communications.

6.3 Wired, computer-controlled communications impairments using traffic control software are ideal for repeatable testing. An example method for interrupting communications is shown in Appendix X1.

7. Procedure

7.1 *Characterize the Impairment:*

7.1.1 The test requestor shall define and describe each communications impairment implementation, type, location, and extent to be tested.

7.1.2 A method to verify the effect of the communications impairments shall be used and the results documented. For example, network connectivity tools such as, “ping” or, “iperf”

can be used to verify the effect of the imposed communication impairments. A best practice is to use the stationary test described in 5.2.1 and 9.4 for the verification.

7.2 Perform A-UGV Tests:

7.2.1 The test requestor shall define a task to be performed by the A-UGV.

7.2.2 *Baseline Test*—A baseline should be established. The baseline task should be initially performed without communications impairments and results documented according to the test method used.

7.2.2.1 Run one or more task repetitions with unimpaired communications to validate that the chosen task can be performed as requested. The baseline test is to be performed in the same space as the impaired tests to be performed. Document the baseline test results (for example, pass/fail, time to completion, stopping distance) to verify that the A-UGV system can complete the task as intended.

7.2.2.2 If it is intended to compare baseline test results with impaired test results, a full test as defined in the test method shall be completed.

7.2.3 Test with Impairments:

7.2.3.1 The test requestor shall define and document the expected A-UGV actions when communications impairments are implemented. Examples of A-UGV actions allowable by the requestor are: stop and resume without human intervention, stop requiring human intervention to restart, hesitation, change in planned navigation path, and change in indicator lighting or sounds. Example expected A-UGV performance can be as follows:

7.2.3.2 A-UGV performance will meet the intended outcome specified in the task being performed.

7.2.3.3 A-UGV performance will not meet the intended outcome specified in the task being performed.

7.3 Describe the expected behavior relative to a baseline result.

7.4 Perform the task as described in Section 8 with communications impairments as requested by the test requestor and results documented. A sample test report is shown in Fig. 2 and examples of completed test reports are shown in Appendix X2 Fig. X2.1 and Appendix X3 Fig. X3.1.

8. Test Method

8.1 The following test methods describe the test procedure to implement A-UGVS communications interruptions at locations shown in Fig. 1 and either:

8.1.1 With the A-UGV stationary and functional, called, “Stationary Test,” or

8.1.2 With the A-UGV tested using a standard test method, called, “Standard Test Method Test.”

8.2 The test requestor may want to consider the manufacturer’s minimum specifications for communications of their A-UGV system within a user’s facility or environment. Beyond the initial A-UGV installation, this test method suggests signal quality testing, vehicle testing, and facility integration testing as required for the intended A-UGV installation and before initiating this test method. Standard test method examples are Test Method F3244 and Test Method F3265.

8.3 The test method(s) chosen shall be appropriate to the application and environment where the A-UGV will be used.

8.4 As noted in 1.8, safety standards for A-UGVs (for example, ITSDF B56.5, ISO 3691-4) should be followed. Inducing communications impairments to the A-UGVS may have unexpected results of which the test administrator, A-UGV operator, and other associated test personnel should be aware.

9. Test Method Procedure

9.1 *Pre-Test Information Collection*—For data traceability and organization purposes, the test supervisor shall obtain and record the pre-test information first using the form shown in Fig. 2. Section 11 will assist the test supervisor in completing this form.

9.1.1 *Date*—The testing date. Some test methods, when explicitly specified, can allow the repetitions to be distributed into multiple days. The time-of-day information may also be included.

9.1.2 *Facility*—Name of the facility in which the test occurs.

9.1.3 *Location*—Names of campus, city, and state in which the facility is located.

9.1.4 *Event*—If there is an event associated with the test, provide the event name.

9.1.5 *Environment*—Fill out the test report described in Practice F3218.

9.1.6 *A-UGV Make*—The name of the manufacturer or developer of the A-UGV and their contact information.

9.1.7 *A-UGV Model*—The specific name and model number, including any extension or remark to identify the particular configuration fully of the A-UGV as tested.

9.1.8 *A-UGV Configuration*—Fill out the test report described in Practice F3327.

9.1.9 *A-UGV Operator*—Give the name, organization, and contact information.

9.1.10 *A-UGV User Organization*—The name and contact information of the organization where the A-UGV is to be installed and used.

9.1.11 *Test Requestor*—Give the name, organization, and contact information.

9.1.12 *Test Supervisor*—Give the name, organization, and contact information.

9.1.13 *Test Technician(s)*—Give the name, organization, and contact information.

9.1.14 *Test Number*—Give test number.

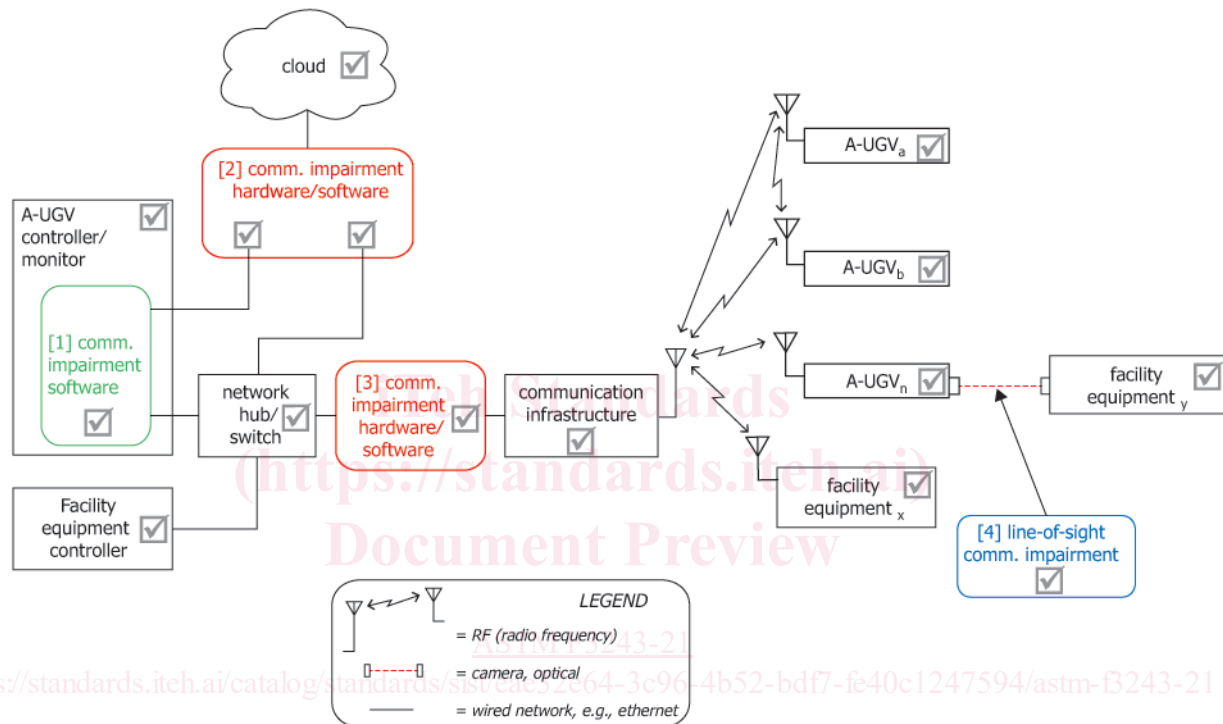
9.1.15 *Required Number of Repetitions*—Give the number of task repetitions to be completed for the test.

9.2 *Test and Task Success*—If the A-UGV performs expected results, as defined by the test requestor before the test, the test has succeeded. If the A-UGV does not perform as defined by the test requestor, the test shall be stopped and the reason for failure shall be documented. This A-UGV test method can only be passed if the defined success criteria is met for a set of repetitions completed as described in the test method. Any such fault events and subsequent necessary actions shall be documented. Examples of success criteria can be:

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DATE: _____	A-UGV MAKE: _____	TEST REQUESTOR: _____
FACILITY: _____	A-UGV MODEL: _____	TEST SUPERVISOR: _____
LOCATION: _____	A-UGV CONFIG: _____	TEST TECHNICIAN: _____
EVENT: _____	A-UGV OPERATOR: _____	TEST NUMBER: _____
ENVIRONMENT: _____	and ORGANIZATION: _____	REQUIRED REPS: _____

A-UGV COMMUNICATION: (describe each component, communication between components, and interruption techniques according to the diagram)



A-UGV System Components

A-UGV Controller/Monitor: _____	A-UGV _a : _____
Network Hub/Switch: _____	A-UGV _b : _____
Facility Equipment Controller: _____	A-UGV _n : _____
Communication Infrastructure: _____	Facility Equipment _x : _____
	Facility Equipment _y : _____

Describe what is used to perform the communication impairment:

Describe how the impairment method was verified:

TEST TECHNICIAN: _____

FIG. 2 (A) Sample Test Report of Communications Interruptions

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TEST TYPE: Stationary Test Standard Test Method Test: _____

Describe the task being performed by the A-UGV:

DIMENSIONED AND LABELED DRAWING OF COMMUNICATIONS TOPOLOGY AND LOCATION BASED IMPAIRMENTS:

(mark where in the apparatus the communications interruption took place; note any features in the apparatus that may be used for communication impairments)

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[ASTM F3243-21](#)

<https://standards.iteh.ai/catalog/standards/sist/eae32e64-3c96-4b52-bdf7-fe40c1247594/astm-f3243-21>

TEST TECHNICIAN: _____

FIG. 2 (B) Sample Test Report of Communications Interruptions (continued)

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Stationary Test
 Standard Test Method Test

DEFINE SUCCESS CRITERIA

 a) _____
 b) _____
 c) _____

 a) _____
 b) _____
 c) _____

Success Criteria

Task Rep	a	b	c	Success	Failure	Notes
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
2	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
4	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
5	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
6	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
7	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
8	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
9	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
10	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
11	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
12	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
13	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
14	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
15	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
16	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
17	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
18	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
19	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
20	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
21	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
22	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
23	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
24	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
25	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
26	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
27	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
28	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
29	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
30	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	

TEST RESULT:
 SUCCESS
 FAILURE
TEST TECHNICIAN: _____

FIG. 2 (C) Sample Test Report of Communications Interruptions (continued)