National Aeronautics and
Space Administration

SLS-RQMT-166

BASELINE

EFFECTIVE DATE: 11/14/2012

SPACE LAUNCH SYSTEM PROGRAM (SLSP) FLEXHOSE AND BELLOWS DESIGN REQUIREMENTS FOR FLOW-INDUCED VIBRATION

Approved for Public Release; Distribution is Unlimited

The electronic version is the official approved document.
Verify this is the correct version before use.

REVISION AND HISTORY PAGE

Status	Revision No.	Change No.	Description	Effective Date
Baseline			Initial Baseline per CECBD SV2-02-0009, dated 11/14/12: (CR SLS-00077); PCN SV00164	11/14/12

TABLE OF CONTENTS

PARAGRAPH **PAGE**

1.0 INTRODUCTION 4
1.1 General 4
1.2 Scope 5
1.3 Change Authority/Responsibility 5
2.0 DOCUMENTS 6
2.1 Applicable Documents 6
2.2 Reference Documents 6
3.0 REQUIREMENTS 7
3.1 Flight System Hardware Requirements 7
3.2 Support Equipment and Facility Hardware Requirements 8
3.3 Resonant Flow Test 9
3.4 Bellows with Atypical Flow Environments 10

APPENDIX

APPENDIX A ACRONYMS AND ABBREVIATIONS AND GLOSSARY OF TERMS 11
APPENDIX B OPEN WORK 12

FIGURE

FIGURE 3.1-1 FLOW CHART FOR FLIGHT HARDWARE 7
FIGURE 3.2-1 FLOW CHART FOR SUPPORT EQUIPMENT AND FACILITY HARDWARE 9

TABLE

TABLE B1-1. TO BE DETERMINED ITEMS 12

1.0 INTRODUCTION

1.1 General

It is well known that the occurrence of flow-induced vibrations (FIV) in convoluted metal bellows and flexhoses contained in fluid ducting systems have resulted in fatigue failures which have forced the premature shutdown of some critical fluid systems. These flow-induced vibrations are a result of the coupling of vortex shedding from the flexible line convolutes with the natural frequencies of the flexible line. This document was written for the Space Launch System (SLS) Program to provide requirements for metal bellows and flexhoses with regards to FIV only. The requirements in this document follow the same general approach used in the Space Shuttle Program via NSTS-08123, Rev. C, Certification of Flexhoses and Bellows for Flow-Induced Vibration. The requirements specified herein are applicable to both flight and ground systems utilizing SLS Program hardware. Two other documents are used in conjunction with this requirements document. The first is George C. Marshall Space Flight Center Drawing No. 20M02540, Revision E, "Assessment of Flexible Lines for Flow Induced Vibration". MSFC-DWG-20M02540 provides a method for determining the susceptibility of metal bellows and flexhoses to flow-induced vibrations. The second is MSFC-SPEC-626, Basic Release, "Test Control Document for Assessment of Flexible Lines for Flow Induced Vibration". MSFC-SPEC-626 specifies the procedures for flow testing metal bellows and flexhoses.

The following exclusions from this specification apply:

a. Metal bellows and flexhoses with flow liners that preclude flow-induced vibration are excluded from this specification.

b. Metal bellows and flexhoses with steady–state flow less than one second duration are excluded from this specification.

c. Metal bellows and flexhoses which experience an operating flow environment that is different than the FIV phenomena described in MSFC-DWG-20M02540 and also beyond the capability of MSFC-DWG-20M02540 to predict are excluded from Paragraphs 3.1 thru 3.3 of this specification but shall be compliant with Paragraph 3.4. This exclusion should be carefully reviewed and receive approval from the appropriate NASA organization.

The requirements, as identified herein, are based upon the Space Shuttle Program philosophy of avoiding those flow ranges which produce flow-induced vibrations.

1.2 Scope

This document specifies the requirements for the design and acceptability of all convoluted metal bellows and flexhoses located in flight and ground systems (Support Equipment [SE] and facilities) in order to prevent failure from flow-induced vibrations. The MSFC-DWG-20M02540 shall be used in conjunction with this document for analyzing a design for susceptibility to flow-induced vibrations. For those bellows or flexhose designs (i.e., welded disc, ring reinforced, toroidal, etc.) which cannot be analyzed by the MSFC-DWG-20M02540, some other approved analysis or testing shall be done.

In determining the acceptability of the design, the analytical procedures found in MSFC-DWG-20M02540 shall be considered of having two phases.

Phase I – Use MSFC-DWG-20M02540 to calculate the flow range at which coupling between flow vortices and the natural frequencies of the bellows or flexhose will occur.

Phase II – If Phase I predicts coupling, use MSFC-DWG-20M02540 to calculate the flow-induced stress at the critical flow velocity and use it as the FIV load input in assessing the fatigue life of the bellows or flexhose. This fatigue life assessment should take into account all load sources (static and dynamic) and not just from FIV.

Flow charts are presented in Figure 3.1-1 and Figure 3.2-1 depicting the process for acceptability.

1.3 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is ER33 at the Marshall Space Flight Center.

Proposed changes to this document will be submitted by an SLS Program change request (CR) to the Chief Engineer Control Board (CECB) for disposition. All such requests will adhere to the SLS-PLAN-008, SLS Program Configuration Management Plan.

2.0 DOCUMENTS

2.1 Applicable Documents

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

Document Number/ Revision	Effective Date	Title
MSFC-DWG-20M02540E	12/19/91	Assessment of Flexible Lines for Flow-Induced Vibration
MSFC-SPEC-626	5/11/1990	Test Control Document for Assessment of Flexible Lines for Flow-Induced Vibration

2.2 Reference Documents

The following documents contain supplemental information to guide the user in the application of this document.

Document Number/ Revision	Effective Date	Title
NSTS-08123C	4/12/94	Certification of Flexhoses and Bellows for Flow Induced Vibration
SLS-PLAN-008A	8/17/12	SLS Program Configuration Management Plan
SLS-SPEC-030-01	11/8/12	SLS Program Support Equipment Specification Volume I, Planning
SLS-RQMT-016A	7/12/12	SLS Program Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) Requirements Document

3.0 REQUIREMENTS

3.1 Flight System Hardware Requirements

The following requirements shall be applicable to all flight hardware regardless of criticality category (refer to SLS-RQMT-016, "SLS Program Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) Requirements Document", for Criticality definitions). In Phase I the MSFC-DWG-20M02540 shall be used to calculate the flow range at which coupling due to FIV occurs. The predicted flow ranges for FIV shall then be compared with the operating flow range of the hardware. When Phase I predicts that no flow induced vibration due to coupling exists over the operating flow range expected (+/-10%), the design shall be acceptable against FIV. When Phase I predicts coupling to occur in the operating flow range, a redesign shall be required to preclude FIV or a Resonant Flow Test (see Paragraph 3.3) shall be required to show an acceptable life. This flow test to show acceptable life shall consist of dwelling at the most severe resonant condition until the number of cycles equivalent to four times the operational life have been accumulated at the resonance condition. If the bellows or flexhose survives this flow test (i.e., shows no indication of fluid leakage or detrimental damage), the design shall be acceptable against FIV. A flow chart for depicting the process for design acceptability is presented in Figure 3.1-1.

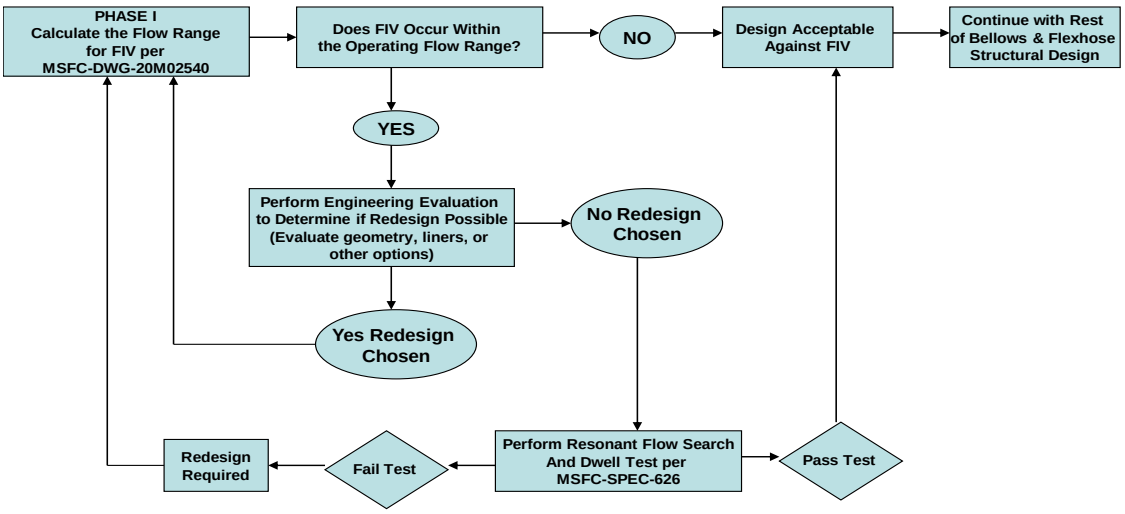

FIGURE 3.1-1 FLOW CHART FOR FLIGHT HARDWARE

3.2 Support Equipment and Facility Hardware Requirements

Support Equipment (SE) which includes Ground Support Equipment (GSE) is that equipment defined in SLS-SPEC-030-01,"SLS Program Support Equipment Specification Volume I, Planning".

For all Support Equipment and facility components where the worst-case potential failure mode is assessed to be Criticality 1, 1R, 2, or 2R as defined in SLS-RQMT-016 then the requirements shall be the same as for flight hardware (see Paragraph 3.1).

For all Support Equipment and facility components where the worst-case potential failure mode is assessed to be Criticality 3 as defined in SLS-RQMT-016 (or is non–critical) and Phase I predicts coupling, then Phase II shall be performed to determine the fatigue life of the bellows or flexhose. In Phase II the MSFC-DWG-25M02540 shall be used to calculate the flow-induced stress. If Phase II predicts an infinite life, the bellows or flexhose design shall then be acceptable against FIV. However, the maximum operating flow velocity through the flexible line shall be limited as set forth in MSFC-DWG-20M02540. If Phase II predicts a finite life, then a redesign shall be required to achieve a predicted infinite life or a Resonant Flow Test (see Paragraph 3.3) shall be required to show an acceptable life against FIV. This flow test to show acceptable life shall consist of dwelling at the most severe resonant condition until the number of cycles equivalent to four times the operational life have been accumulated at the resonance condition. If the bellows or flexhose survives this flow test (i.e., shows no indication of fluid leakage or detrimental damage), the design shall be acceptable against FIV. A flow chart for depicting the process for design acceptability is presented in Figure 3.2-1.

It is recognized that ground systems may be Criticality 1 or 2 while their individual components may be Criticality 3 or noncritical.

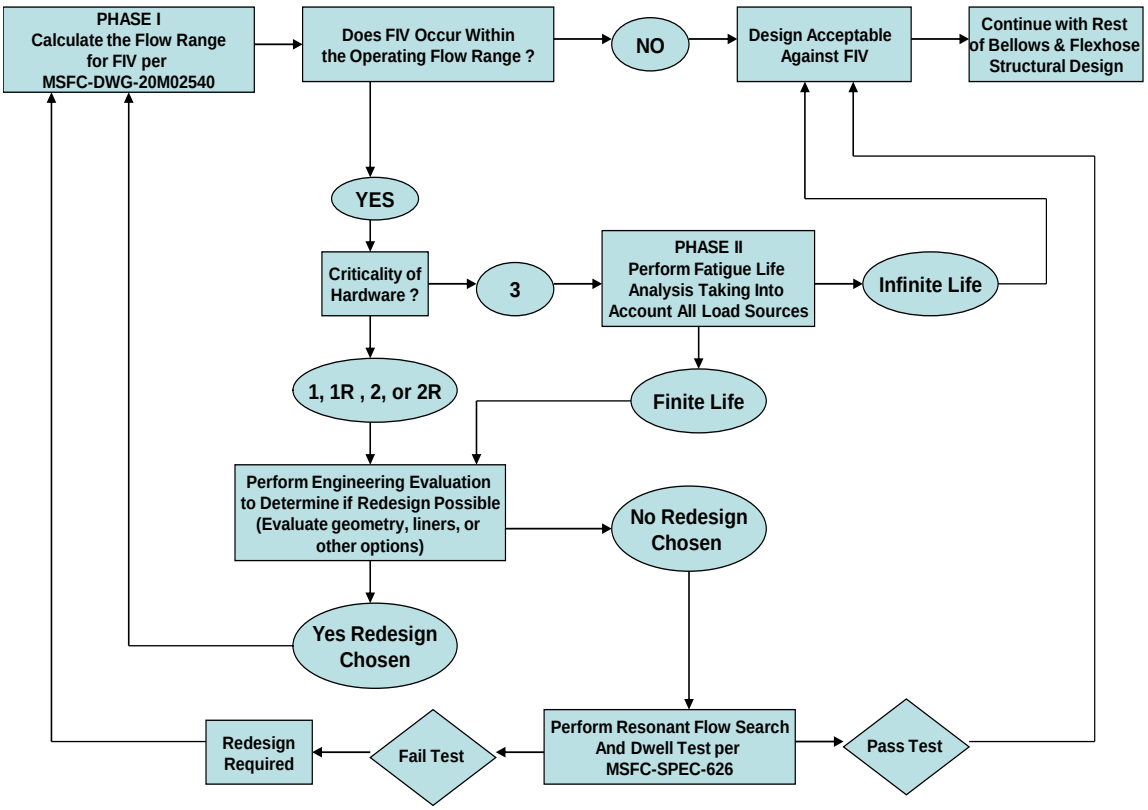

FIGURE 3.2-1 FLOW CHART FOR SUPPORT EQUIPMENT AND FACILITY HARDWARE

3.3 Resonant Flow Test

A Resonant Flow Test is defined as one in which the bellows or flexhose is instrumented with strain gages and/or accelerometers. A Resonant Flow Test consists of two parts. The first part is a resonance search test to determine if flow coupling occurs and, if so, at what flowrate and frequency. The second part is a resonance dwell test to determine the life of the flexible line while flowing at the most severe resonant condition. The Resonant Flow Test shall be conducted in accordance with MSFC–SPEC–626.

3.4 Bellows with Atypical Flow Environments

For metal bellows and flexhoses which experience an operating flow environment that is different than the FIV phenomena described in MSFC-DWG-20M02540 and also beyond the capability of MSFC-DWG-20M02540 to predict then an alternative analysis technique shall be used. This exclusion from MSFC-DWG-20M02540 and the use of an alternative analysis technique shall be approved by the appropriate NASA organization. The alternative analysis technique and assumptions used during the design phase shall be shown to be conservative through an appropriate test program. The test program shall be developed with approval from the appropriate NASA organization.

APPENDIX A
ACRONYMS AND ABBREVIATIONS AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

FIV	Flow Induced Vibration
GSE	Ground Support Equipment
SE	Support Equipment
SLS	Space Launch System
OPR	Office of Primary Responsibility
CECB	Chief Engineer's Control Board

A2.0 GLOSSARY OF TERMS

Term	Description
Free Bellows	Where convolutes have unrestricted movement when exposed to fluid flow impingement.
Flexhose	A flexible metal hose where convolutes are partially restrained at the crown by wire braid.
Flexible Line	A metal bellows or flexhose assembly that joins two duct sections and permits relative motion between the ducts in one or more planes.
Operational Life	The time accrued when the number of missions is multiplied by the mission system operation time plus any ground checkout operations.
Resonant Flow Test	See Paragraph 3.3.

APPENDIX B
OPEN WORK

B1.0 TO BE DETERMINED

Table B1-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is sequentially numbered as applicable (i.e., **<TBD-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

Table B1-1. To Be Determined Items

TBD	Section	Description