Attachment REQ-9, Approved Flexible Hose Restraints and Thrust Load Evaluations

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/2014	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/2023	New document title to match new ESM Ch. 17 formatting (formerly known as Section ASME - New ASME System Requirements, Attachment ASME-4-1, Flexhose and Relief Device Restraint). Moved additional flex hose restraint content from main ESM Ch. 17 Sections to this attachment.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

1.0 PURPOSE

This document provides a listing of approved flex hose restraints and one acceptable method/example for designer approval of alternative flex hose restraint by determining thrust load. This same method can be used for thrust load determination of relief devices or their outlet piping to be used as an input to design of their supports.

2.0 APPROVED PARKER FLEX HOSE RESTRAINTS

Parker Hannifin flex hose restraints provide acceptable protection against whipping in the event of flex hose failure (most commonly shear at the fitting) up to the size/pressure values listed in the table below. For all other hoses, the designer is responsible to evaluate the material of construction and the anchor location to ensure the alternative is a safe design based on a thrust load calculation like the one later in this document.

Per the Parker Hose Whip Restraint Bulletin 4480-148 © 2009 Parker Hannifin Corp: "The Whip Restraint System has been tested to the operating pressures of the hoses listed in HPD Catalog 4400."

The HPD Catalog 4400 © 2011 Parker Hannifin Corporation has multiple types of hoses listed. The highest rating for a given size is shown below in Table 1.

Table 1: Highest Hose Ratings listed in Catalog 4400

Hose Size Designation	Hose Size (inch)	Highest Hose Rating	Hose Type
-4	1/4	10,500	Hydraulic JK
-5	5/16	5,000	Hydraulic 302
-6	3/8	10,000	Hydraulic JK
-8	1/2	6,000	Constant Working Pressure 797TC
-10	5/8	6,000	Constant Working Pressure 797TC
-12	3/4	6,000	Constant Working Pressure 797TC
-16	1	6,000	Constant Working Pressure 797TC
-20	1 1/4	6,000	Constant Working Pressure 797TC
-24	2	6,000	Constant Working Pressure 791TC
-32	2 1/2	5,000	Constant Working Pressure P35
-40	3 1/4	350	Transportation 201
-48	4	200	Transportation 201

Thus, the Parker Hose Whip Restraint may be used to the maximum value as shown in HPD Catalog 4400. An example of a Parker hose restraint installation is provided in Figure 1 below.

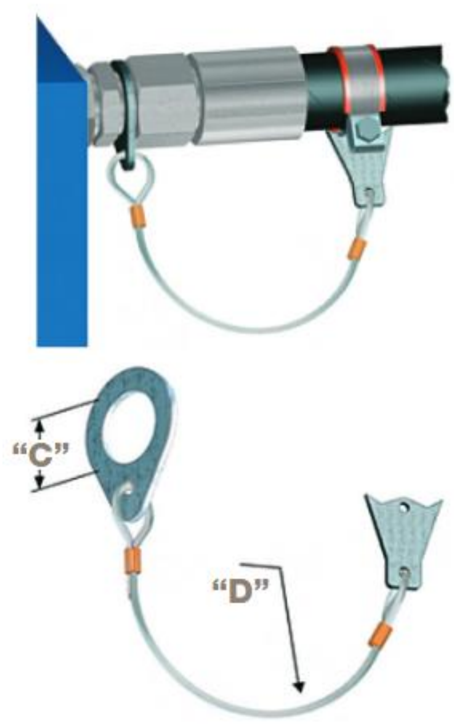

Figure 1. Parker Hose Whip Restraint

3.0 APPROVED ALTERNATIVE FLEX HOSE RESTRAINTS

Self-restraining flex hoses like Air Liquide's LifeGuard Safety Hose Anti-Whip Internal Safety System and Global Passive Safety System's LifeGuard meet the requirements of this chapter for preventing flex hose whip. Figure 2 below provides a visual example of a self-restraining flex hose.

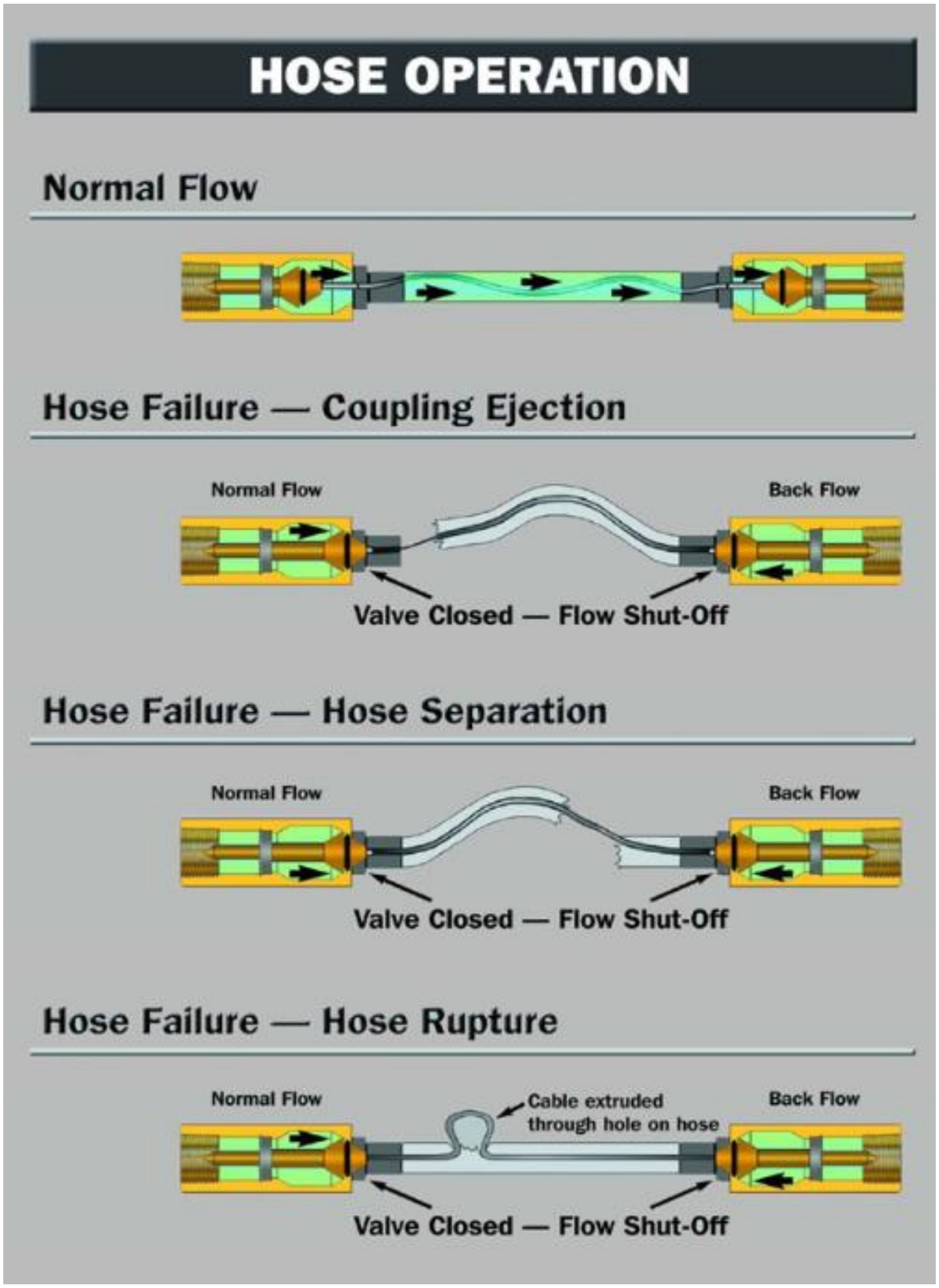

Figure 2. Self-Restraining Flex Hose

Hose sock grips (a.k.a., whip socks) from brands such as Kellems may be used within manufacturer guidelines for pressure and hose size restrictions.

Clamp-on hose restraints from brands such as Adel may be used within manufacturer guidelines for pressure and hose size restrictions.

Examples of hose sock and clamp-on restraint installations are provided in the figures below.

Figure 3a. Example of a Hose Sock (whip sock)

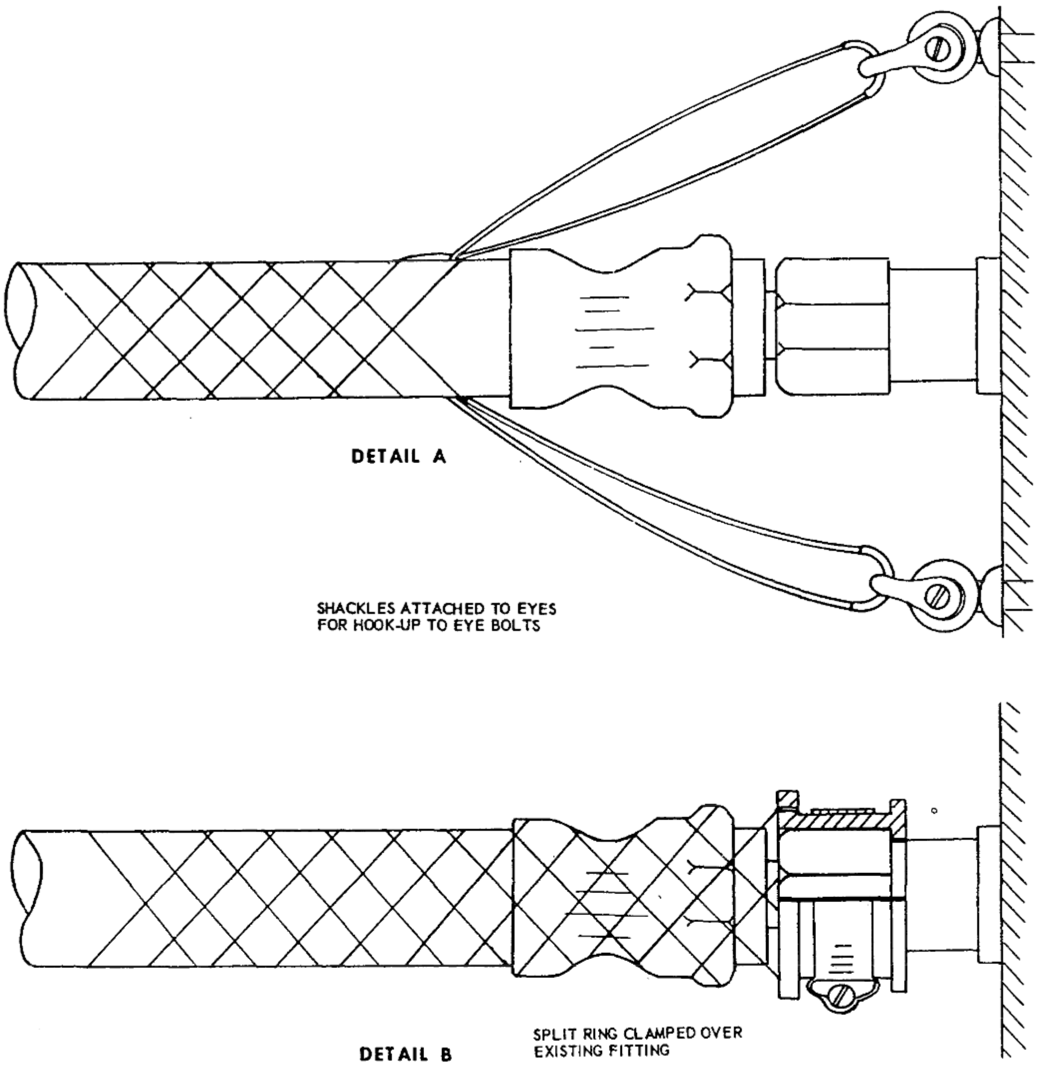

Figure 3b. Example of a Hose Sock (whip sock)

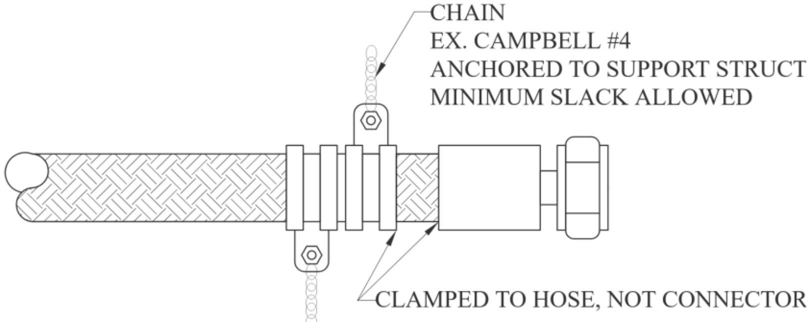

Figure 4. Example of a Clamp-On Restraint

4.0 DESIGNER APPROVAL OF ALTERNATIVE FLEX HOSE RESTRAINTS AND CALCULATING THE CONSERVATIVE CASE THRUST MODEL

The example below is for a full gas cylinder at 2265 psig.

Estimating the initial surge thrust from an open line based on the assumption that the gas is exiting at sonic velocity, the mass flow rate results from the initial (pre-flow) density and sonic velocity, and that the pressures at the outlet of the tube has decrease to the highest pressure that maintains sonic flow (the critical pressure ratio). This is a worst-case condition and would probably only last a very short time duration until line losses resulted in a decrease in the mass flow and outlet pressure. In addition, the gas temperature will decrease due to isentropic expansion.

Reference: *Introductory Gas Dynamics*, Chapman and Walker, 1971 Ed. Page 273 Equation 7.7

Thrust, $T = m' V + P_o A$ where:

m′ mass flow rate

V′ gas outlet velocity

P_o outlet pressure

A Area of the outlet

$m' = rho/g\ v_s A$ mass flow rate based on upstream density (rho), sonic velocity (v_s), and inside diameter

$V = v_s$ outlet gas velocity is sonic velocity

rho = P/RT density based on ideal gas behavior, where:

P absolute pressure

R Gas Constant

T absolute temperature

$V_s = (k\ g\ R\ T)^{1/2}$ sonic velocity for an ideal gas, where:

k ratio of specific heats

g acceleration due to gravity

$P_o = P/PR_c$ outlet pressure based on upstream pressure and critical pressure ratio

critical pressure ratio, reference *Orifice Meters With Supercritical Compressible Flow*, Cunningham, page 635, formula 20, inverse of formula used for upstream to downstream pressure

$PR_c = [(k + 1)/2]^{(k/(k-1))}$

General Thrust Equation: $F = m_e w - m_i V_o + (P_e – P_o) A_e$, where:

F = Thrust

m_e = Exit Mass Flow Rate

w = Velocity of exit gas

m_i = Inlet mass flow rate

V_o =Velocity of Free-Stream Air (flight speed)

P_e = Absolute Static Pressure in Exit Section of Exhaust Nozzle

P_o = Absolute Static Pressure of Free-Stream Ambient

A_e = Cross-Sectional Area of Exit Section of Exhaust Nozzle

Solving for thrust:

$T_s = [(P/(RTg)) ((k g R T)^{1/2}) A] ((k g R T)^{1/2}) + [P/[((k+1)/2)^{(k/(k-1))}] A$

Simplifying the equation:

$T_s = PA \{k + 1/[((k+1)/2)^{(k/(k-1))}]\}$

Defining the value within the bracket as the Surge Thrust Factor (STF):

T_s = PA STF

Example: Surge thrust forces for various flex hose sizes with argon with a maximum internal pressure of 2265 psig:

k (argon) = 1.67

Rc (Critical Pressure Ratio) = 2.05

STF (argon) = 2.16 (bounding condition)

Result:

Table 2 Calculated Surge Thrust (example, argon @ 2265 psig)

Flex Hose ID (fractional inch)	Flex Hose ID (decimal inch)	Internal Area (Pi*D^2/4), (in^2)	Argon Surge Thrust Factor	Surge Thrust (lbf)
1/8"	0.125	0.0123	2.16	60
1/4"	0.25	0.0491	2.16	240
5/16"	0.3125	0.0767	2.16	375
3/8"	0.375	0.1104	2.16	540
7/16"	0.4375	0.1503	2.16	735
1/2"	0.5	0.1963	2.16	961
9/16"	0.5625	0.2485	2.16	1216
5/8"	0.625	0.3068	2.16	1501
11/16"	0.6875	0.3712	2.16	1816
3/4"	0.75	0.4418	2.16	2161

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Flex Hose ID (fractional inch)	Flex Hose ID (decimal inch)	Internal Area (Pi*D^2/4), (in^2)	Argon Surge Thrust Factor	Surge Thrust (lbf)
7/8"	0.875	0.6013	2.16	2942
1"	1	0.7854	2.16	3842
1 1/4"	1.25	1.2272	2.16	6004
1 1/2"	1.5	1.7671	2.16	8646
1 3/4"	1.75	2.4053	2.16	11768
2"	2	3.1416	2.16	15370
2 1/4"	2.25	3.9761	2.16	19453
2 1/2"	2.5	4.9087	2.16	24016
2 3/4"	2.75	5.9396	2.16	29059
3"	3	7.0686	2.16	34582
3 1/4"	3.25	8.2958	2.16	40586
3 1/2"	3.5	9.6211	2.16	47070
3 3/4	3.75	11.0447	2.16	54035
4"	4	12.5664	2.16	61480

Brackets, supports, hose restraints, or whip restraints must be designed to meet or exceed the surge thrust calculated.