Practices for Pressure Relief Valve Discharge Piping

By Greg Uhrhan, P.E.

Abstract

Many mechanical refrigeration systems containing large quantities of refrigerant possess pressure relief devices. Under certain conditions, these systems are piped to the outdoors to prevent the displacement of air inside a structure. This paper is intended to give a list of best practices for sizing the piping from the discharge of a pressure relief valve to the outside.

Introduction

Proper and safe operation of a mechanical refrigeration system is dependent on numerous controllable variables. However, during certain extreme scenarios, ranging from failures to fire, safety dictates the use of a pressure relief valve to prevent explosion or catastrophic air displacement due to refrigerant release. For many systems containing large quantity of refrigerant, these pressure relief devices must be piped to the outdoors to prevent the displacement of air inside a structure. APC cooling products typically have a pressure relief valve located at the receiver of larger products. This valve is sized according to ASHRAE 15-2001 Safety Standard for Refrigeration Systems specifications. However, APC does not specify the piping from the valve to the outside of the building due to the nearly limitless number of variables in building design. Listed below are the guidelines.

Use of Pressure Relief Valves

ASHRAE 15, the Uniform Mechanical Code (UMC), and UL 1995 specify that all receivers should be protected with a pressure relief device at the receiver in order to be in compliance with those standards. APC products utilize a pressure relief valve in order to prevent dangerous pressure buildup. Currently on APC cooling products (AFX, CM, FM series, and the ACRP100 series) utilize a pressure relief valve. Details of each are in **Table 1**.

Aforementioned standards also indicate that units over 110 lbs [50 kg] of a Class A1 refrigerant shall be piped outside after leaving the relief valve. Group A1 refrigerants include but are not limited to R22, R407c, and R410a, the three most commonly used by APC cooling products. Local codes may limit this charge weight to considerably lower limits and should be investigated by the design engineer.

Best Practice for Piping APC Products

In order to maintain system integrity during a worst case scenario where the cooling unit is in a building on fire, the use of copper piping is highly recommended. The pipe shall be at least the same size as the outlet diameter. Pressure relief valves should not be capped, although certain local codes may allow it, it is never recommended.

To minimize impedance to flow, effort should be taken to minimize the number of required bends and to use long radii when bends are needed.

Table 1 – Relief valve Info for APC products

Product	Pressure relief part number	Throughput lbm/min [kg/min]	Pressure set point (psi [bar])	Outlet diameter (in [mm])	Connection (in [mm])
ACRP 100 series	875-4230	16.1 [7.3]	425 [29.3]	½ [12.7]	½ flare [12.7 flare]
FM series, R22 units	875-4230	16.1 [7.3]	425 [29.3]	½ [12.7]	½ flare [12.7 flare]
FM Series R407c units	875-4247	17.0 [7.7]	450 [31.0]	½ [12.7]	½ flare [12.7 flare]
CM	875-4230	16.1 [7.3]	425 [29.3]	½ [12.7]	½ flare [12.7 flare]
AFX	875-4122	17.0 [7.7]	450 [31.0]	3/8 [9.5]	3/8 flare [9.5 flare]

Discharge from Structure

The discharge is required to be at least 15 feet [4.54 m] above ground level, and at least 20 feet [6.06 m] from any window, door, or ventilation port. The discharge should be terminated in a manner that prevents discharged refrigerant from being directly sprayed at individuals nearby and prevents debris from entering and clogging the discharge port. A specially designed diffuser is recommended, such as a Whisper-Flo Vent Diffuser for example.

Common Discharge Headers

Where multiple units tie to a common discharge header, the header shall be sized such that it has at least the cross sectional area of the combined pipes feeding into it. Check valves may be used to ensure unidirectional flow in the pipes between the unit and the header; however, one must consider the pressure loss through a check valve when designing the discharge piping.

Condenser Pressure Relief Valves

Often air cooled condensers are fitted with pressure relief valves, especially when built with a flooded receiver package. These pressure relief valves will always be located outdoors on the condenser, so it is unnecessary to pipe them in any special manner. Condenser pressure relief valves, when present, should be set to crack open at a lower pressure than the indoor unit so that in a normally functioning unit, any discharge occurs outside. However, this does not absolve the need to pipe the indoor discharge outdoors for units meeting previous requirements for charge weight. Often solenoid valves, check valves, or Rotolock valves can obstruct the refrigerant from flowing out of the receiver to the condenser. The designer should review the entire refrigeration piping loop for potential flow restrictions or blockages that may prevent total charge discharge.

Procedure for Piping Selection

Required variables:

- Atmospheric pressure , P_2 in psi, [kPa], (or altitude, Z, in feet [meters])
- Valve pressure pating, P (psi [kPa])
- Valve throughput , C_r (lb/min of air [kg/s of air])
- Size of piping (outside diameter), OD (inches [mm])

Calculated and lookup variables:

- Backpressure at discharge of pressure relief valve, P_0 (psi [kPa])
- Moody friction factor, f
- Internal size of piping (inside diameter), d or ID (inches [mm])

Output variables:

- Maximum equivalent length of piping, L (ft [m])

Governing Equations

$$L = \frac{.2146 \times d^5 \times \left(P_0^2 - P_2^2\right)}{f \times C^2} - \frac{d \times \ln\left(P_0 / P_2\right)}{6 \times f} \qquad \text{(Eq. 1)}$$

$$\left[L = \frac{7.4381 \times 10^{-15} \times d^5 \times \left(P_0^2 - P_2^2\right)}{f \times C^2} - \frac{d \times \ln\left(P_0 / P_2\right)}{500 \times f} \right]$$

Where

$$P_0 = (.15 * P) + P_2 \quad \text{(Eq. 2)}$$

Auxiliary Functions

$$P_2 = 14.696 \times (1 - Z \times 6.8753 \times 10^{-6})^{5.2559} \quad \text{(Eq. 3)}$$

$$\left[P_2 = 101.325 \times (1 - Z \times 2.25577 \times 10^{-5})^{5.2559} \right]$$

Where Z is the altitude in feet [m]

Altitudes and mean atmospheric pressure can be found in ASHRAE climatic data in the ASHRAE Fundamentals Handbook, or by requesting info from local airport.

Tables for lookups

Table 2 – Inside diameter and Moody friction factor f as a function of outside diameter

Copper pipe OD (in [mm])	ID (in [mm])	f
3/8 [9.5]	.315 [8.00]	.0136
1/2 [12.7]	.430 [10.92]	.0128
5/8 [15.87]	.545 [13.84]	.0122
3/4 [19.05]	.666 [16.92]	.0117
7/8 [22.22]	.785 [19.94]	.0114
1 1/8 [28.58]	1.025 [26.04]	.0108

Table 3 – Pressure at altitude

Altitude (ft [m])	Mean air pressure (psia [kPa])
0 [0]	14.696 [101.325]
1000 [305]	14.173 [97.719]
2000 [610]	13.665 [94.217]
3000 [914]	13.171 [90.811]
4000 [1219]	12.692 [87.508]
5000 [1524]	12.228 [84.309]
6000 [1829]	11.777 [81.200]

Example 1

You are installing an ACRP100 at sea level. You desire to use 3/4 inch pipe. What is the maximum equivalent length permissible for the discharge piping?

Solution

An ACRP has a valve rated to open at 425 psi, with a throughput of 16.1 CFM of air. At sea level, mean ambient air pressure of 14.7 psia. Therefore, P_0 = .15*425 +14.7 = 78.5 psi.

$$L = \frac{.2146 \times .666^5 \times \left(78.5^2 - 14.7^2\right)}{.0117 \times 16.1^2} - \frac{.666 \times \ln\left(78.5/14.7\right)}{6 \times .0117} = 39.2\,ft$$

Therefore, the maximum equivalent length with a 3/4 inch pipe is 39.2 feet.

Solution's Note:

More often than not, the diameter is not fixed, but the desired length or equivalent length is known, therefore, the maximum length calculation should be used to determine if the desired pipe size is adequate. Unfortunately, since the maximum length equation is a 5th order polynomial, reverse solving it for the pipe size can yield up to 5 solutions. Also, the friction factor changes with each pipe size and should be taken into account properly.

Also, for engineers not familiar with the concept of equivalent length, the equivalent length is the length of straight pipe which produces a pressure loss equivalent to the straight pipe lengths plus the losses in elbows, tees, valves, reductions and expansions. See below table for elbow and tee losses.

Table 4 – Equivalent lengths as a function of copper pipe outside diameter

Copper Pipe OD (in [mm])	Standard 45 degree elbow	Standard 90 degree elbow	Tee, straight flow	Tee, branch flow
3/8 [9.5]	.1	.5	.1	1.5
1/2 [12.7]	.5	1	.2	2
5/8 [15.87]	.5	1.5	.3	2
3/4 [19.05]	.5	2	.4	3
7/8 [22.22]	.8	2.2	.5	3.8
1 1/8 [28.58]	1.0	2.6	.5	4.2

Therefore, a pipe system of ½ inch pipes with a 10 ft straight length followed by a long radius elbow, 3 feet of straight, a straight through a tee, and 14 more feet of straight would have a pressure loss of 10+1+3+.2+14 = 28.2 feet of Equivalent Length.

Other types of losses can be found in ASHRAE Fundamentals Handbook.

Example 2

You are installing an ACRP101 in Denver, Colorado (elevation 5280 ft). The optimal discharge location will require 80 feet of equivalent length. What pipe size should be used?

Solution

An ACRP has a valve rated to open at 425 psi, with a throughput of 16.1 CFM of air. Denver, at 5280 ft, has a mean ambient air pressure of $P_2 = 14.696 \times (1 - 5280 \times 6.8753 \times 10^{-6})^{5.2559}$ = 12.1 psia using equation 3. Therefore, with 3/4 inch pipe, P_0 = .15*425 +12.1 = 75.9 psi.

$$L = \frac{.2146 \times .666^5 \times \left(75.9^2 - 12.10^2\right)}{.0117 \times (16.1 \times .0764)^2} - \frac{.666 \times \ln(75.9/12.1)}{6 \times .0117} = 34.6\,ft$$

Therefore, the maximum equivalent length with a 3/4 inch pipe is 34.6 feet, which is too short.
Comparatively, you try using 7/8“ pipe.

$$L = \frac{.2146 \times .785^5 \times \left(75.9^2 - 12.10^2\right)}{.0114 \times (16.1 \times .0764)^2} - \frac{.785 \times \ln\left(75.9/12.1\right)}{6 \times .0114} = 100.5\,ft$$

Therefore, the 7/8" pipe meets the acceptable criteria.

About the Author:

Greg Uhrhan is a Mechanical Engineer for APC. He is responsible for cooling system design, technical data, and system applications. Greg received a Bachelor's degree in Mechanical Engineering from University of Illinois at Urbana - Champaign in 2001, a Masters in Mechanical Engineering from Georgia Tech in 2005, is a member of ASHRAE and ASME, and is a licensed Professional Engineer in the State of Missouri.