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Performance of expellers in evacuating gas pipelines—Part I: Measurements, models and field verification

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Abstract

This is a two-part paper. Part (I) presents results of measurements conducted on two different types of expellers of various sizes mounted on matching or mismatching size stacks, with equivalent flow resistance imposed by the gas pipeline section. Expeller performance in terms of its induction ratio has been found to be correlated to the system equivalent flow resistance coefficient in the form of a power-law. It was also found that the induction ratio deteriorates significantly as flow resistance is increased, and that manufacturer's specifications are typically given for full-size free-access inlet (i.e. with no flow resistance). In the field this is never the case, and hence the methodology adopted here in quantifying the performance characteristics is useful in practical applications. A model based on these characteristics has been developed for any asymmetric expelling system. Model results indicate that there is a stonewall limiting characteristic of the system beyond which, a larger size expeller does not induce higher suction flows. Two practical aspects are highlighted: (1) requirements for equal suction flows on both sides of the work-site and (2) time to complete one full sweep of pipeline gas with ambient fresh air. Effects of plug valves installed on blowdown stacks and effects of driving the expellers with natural gas are discussed in a companion paper (Part II).

Keywords: Expelling; Evacuation; Induction; Combustible gas mixtures; Confined space; Gas pipeline; Hot tapping; Air movers; Blowdown

1. Introduction

Air movers (expellers) are portable devices used to evacuate remaining natural gas in an isolated section of a pipeline following blowdown from line pressure to ambient pressure. The evacuation procedure is necessary prior to commencing any cuts or repair work at any location along the section of the line (work-site). Unlike blowers, expellers do not employ any moving parts, but operate on a low pressure combined venturi and Coanda effects created by the compressed air flowing through circumferential annular gap or set of holes at the bottom of the device, as shown in the schematic of Fig. 1 (top). The venturi concept is similar to that employed in subsonic ejectors [1–5].

In practice, expellers are installed on blow-offs (blowdown stacks) on each end of the pipeline section to draw air into the pipe at the work site [6–9] and move combustible gas through the pipe toward the expeller (Fig. 1). Compressed air (up to 700 kPa g) is used to drive expellers, which allows the operator to control the amount of airflow introduced at the opening at the work-site towards either expeller.

The American Gas Association (AGA) provided guidelines [10] for selecting the size of the expeller to be used and the ranges of air pressure for a given stack configuration and pipeline conditions. This guideline, also provides a procedure for displacement of the gas with air in a sequence that insures safe repair operations, including hot cutting, cold cutting, and during welding of a new spool piece.

The amount of air drawn to either side of the work-site is typically determined by attaching streamers to the upstream and downstream edges of the access hole or the end

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Nomenclature

A_o	orifice area	L	pipe length
A^*	expeller hole area	$\dot{m}$	mass flow rate
β	orifice to pipe diameter ratio	P_0	drive air pressure
c	concentration of gas in air	Q_s	suction flow rate
C_1	constants	Q_d	drive air flow rate
C_2	constants	R	gas constant for air
C_d	discharge coefficient	t	time
D	pipe internal diameter	T_0	drive air temperature
f	Fanning friction coefficient	u	mean flow velocity
IR	induction ratio (Q_s/Q_d)	WT	pipe wall thickness
k	isentropic exponent	ρ	ambient air density
K_e	equivalent resistance coefficient	ψ	turbulent diffusion coefficient
K_o	opening pressure loss coefficient		
K_{line}	pipeline pressure loss coefficient	*Subscripts*	
K_{ent}	entrance pressure loss coefficient	e	expeller
K_{stack}	stack pressure loss coefficient	p	pipe
		s	stack

of the pipe and observing the deflection angle of the streamers. Drive air pressures at the expelling ends are adjusted to maintain equal flow of air in both directions. Obviously this technique is very subjective, and in many cases equal flows cannot be maintained due to the asymmetry of the two sides in terms of pipeline/stack dimensions and different sizes of expellers used at either end.

Additionally, longer sections of pipelines to be evacuated introduce a relatively high flow resistance to the expeller. Typically, published performance data by respective manufacturers of expellers in terms of the induction ratio (ratio of suction flow to drive air flow) is specified with full-size free-access (i.e. inlet of expeller is open to atmosphere). Therefore, there is a lack of understanding and information on the performance characteristics of any given expeller used on any given pipeline section.

This paper presents results of measurements conducted on two types of expellers from two different manufacturers: referred to as Type-A, and Type-B in this paper. Different size expeller/stack geometries were tested in order to quantify the effects of size-on-size vs. size-on-different-size expeller/stack arrangement. Flow resistance imposed by a pipeline section attached to the expeller/stack assembly is

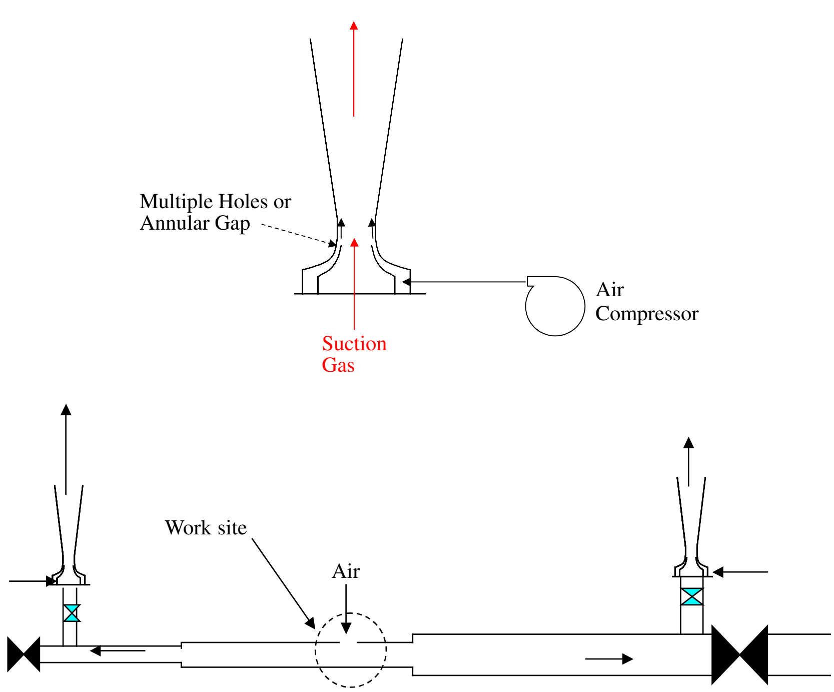

Fig. 1. Operating principle of an expeller, and a schematic of a general two-sided pipeline expelling operation.