The first order dead time is determined by the front-end transfer to the BDC as long as the BDC FIFO are not saturated. The saturation rate is given by the average time spent by the data acquisition processor per event. Details of the data acquisition program are available in references [42]. An average time of 4.2 ms per event is needed. This corresponds to an average of 237 hits in 10 bunch crossings.

2.6 Gas systems

To operate the nine different tracking detectors nine separate gas circuits are necessary, with different gas mixtures, flows, and demands on purity and overpressure control. For the forward chambers and CJC closed circuits are used while CIZ, COZ, CIP, COP and BWPC are flushed with premixed gases in open circuits. The main parameters of the gas systems are given in Table 7.

Detector	Gas volume	Gas mixture + additives: volume ratio	Pressure relative to atmosphere		Flow rate		System
			typ.	max.	typ.	max.	circuit
	[l]	[%]	[hPa]		[l/min]		type
Planars+ FWPC	~900	$Ar/C_3H_8+C_2H_5OH$ (90/10)+1	0.15±0.10	1	1.3	3	I closed
Radials	~700	Phase I: Ar/C_2H_6 (48/52) Phase II: $Xe/C_2H_6/He$ $+C_3H_7OH$ (20/40/40)+1	0.15±0.10	1	1.0	2	
Radiators	~500	He/C_2H_6 (60/40)	0.25±0.10	1	0.1	1.5	open
CJC1	~1140	Phase I: $Ar/CO_2/CH_4$ (89.5/9.5/1)	1.5±0.5	5	1.5	3	II closed
CJC2	~3080	Phase II: $Ar/C_2H_6+H_2O$ (50/50)+0.5	1.5±0.5	5	4.5	9	
CIZ	~55	$Ar/C_2H_6+H_2O$ (70/30)+0.2	0.15±0.10	1	0.1	0.6	III open
COZ	~240	$Ar/C_2H_6+C_3H_7OH$ (48/52)+1	0.15±0.10	1	0.2	0.8	
CIP	~30	Ar/C_2H_6/Freon12$+H_2O$ (49.9/49.9/0.2)+0.2	0.15±0.10	1	0.07	0.6	
COP	~150	Ar/C_2H_6/Freon12 (49.9/49.9/0.2)	0.15±0.10	1	0.1	0.6	
BWPC	~120	Ar/C_2H_6/Freon12 (49.9/49.9/0.2)	0.15±0.10	1	0.1	0.6	

Table 7: The different circuits of the gas systems.

2.6.1 Gas circuits

The simplified diagram of the gas circuit of the planar chambers shown in Figure 15 illustrates the typical features of the gas systems. The system is distributed over three levels, the supply outside the H1 hall, the control room on the first underground floor and finally the distribution rack on top of the electronics trailer near the detector. At the latter point the gas inlet flow for each detector is adjusted by mechanical flow meters and for some chambers split into several streams for further distribution as shown in Figure 15. The static pressure of chambers relative to atmosphere is measured with sensors in the μbar range. In order to avoid too large hydrostatic pressure differences between chambers and sensors, the latter are also located at this point.

From the inlet manifold either pure or premixed gases can be fed into the circuit. Flushing is done by gently filling helium or argon via the two flow meters FL1-1 and FL1-2 into the chambers, while the chamber gas at the same time is sucked out by the membrane pump CP1-1. To hold the chamber pressure during the whole operation within adjustable tolerances of about ± 100 μbar, the solenoid valves SV1-2 and SV1-3 will be either opened or closed depending on the actual pressure inside the detector. As seen from Figure 15, the ingoing and outgoing flows of the chamber gas are split into two paths, one of them containing instruments for continuous gas analysis like infrared meters, a hygrometer and a gas chromatograph in combination with an oxygen trace analyzer. The filling of the chambers proceeds in a similar way as the purging either with premixed gas or by introducing approximately the right proportions of first the non-flammable and later the flammable gases. Then inlet and vent valve are closed and the circuit is switched from the open to the closed mode. The gas circulates through the barrel, the purification units, if needed, through an alcohol or water bath, and through the chambers. Since the purification units absorb part of the gas components, particularly hydrocarbons, a readjustment of the mixture is necessary after typically one day of circulation. To maintain the correct mixture gas can be added to the barrel manually. Repeated circulation for several days, especially when additives like water or alcohol are used, leads then to a homogeneous gas mixture constant in time.

So far three types of additives are used. Some mixtures contain 0.2 % Freon 12 as one of the components of the premixed gas. To other delivered mixtures alcohol (typically 1 %) or water (typically 1000 ppm) is added by passing the gas over a bath of the cooled or frozen liquid stored in a refrigerator in temperature controlled reservoirs. The admixture is adjusted by varying the bath temperature.

2.6.2 Purification and analysis

The closed loop circuits are supplied with purification units for removing oxygen, water and low concentrations of higher organic compounds. For oxygen removal 2 kg BTS-catalyst R3-11 [43] in the reduced state is used as an absorption agent and oxygen levels as low as 20 to 40 ppm have been reached over long time periods. Optimal oxygen removal is obtained with catalyst temperatures of 100 °C to 150 °C. However in the case of ethanol admixture, as is foreseen for the planar chambers, the alcohol will be cracked [44, 45]. Working at temperatures below 80 °C circumvents this problem at the cost of a lower oxygen capacity for the purifier of only about 6 to 15 l [O_2/kg (catalyst)]. A similar problem arises when isopropanol is added to the chamber gas, which is recommended for Stablohm wires and the radial chambers [25, 46]. Since the isopropanol molecule is more fragile than the ethanol molecule, it is cracked even at room temperature into hydrogen and acetone by the catalyst [47]. Use of other O_2-purifiers working at low temperature like Oxisorb [48] and palladium-catalyst [49] give similar problems with alcohol-additives, especially with isopropanol, so that up to now isopropanol could not be used in the closed circuit of the radial chambers.

At room temperature water and higher organic compounds are removed by a mixture of 1.5 kg 3 Å and 0.5 kg 5 Å molecular sieves. In case of water or ethanol additives the molecular sieve eventually saturates, but it is still capable of removing other impurities. Both, molecular sieve and BTS-catalyst are regenerated twice per year or whenever necessary.

Continuous control of gas composition is necessary for constant operation. Infrared meters, dedicated to a certain gas type, but with some sensitivity left for the gas additives give permanent information on changes. Hygrometers in the ppm-range and an O_2-trace analyser allow an early detection of leaks. Complete analysis of the gas composition is performed by an automatic gas chromatograph station, routinely switched into the different circuits. Independently of the use of calibrated gases this instrument gives the different gas portions to an accuracy of ± 2 % of the measured value with an overall sensitivity of about 300 ppm [50, 51].

2.6.3 Electronic control and safety

The concept of the H1 gas system control follows the solution chosen for L3 time expansion chamber (TEC) [52, 53]. A Motorola 68000 CPU serves as a crate master, integrated into a VME-system with the necessary resources for monitoring, logging and control equipment. The instantaneous values of all analog outputs of the measuring devices, especially those for pressure and temperature, but also those for supply voltages are controlled within preset limits. Warnings or alarms are generated if one of the relevant parameter values is exceeded. In case of an alarm the gas circulation is stopped and the HV supplies of the detectors concerned are switched off. A computer independent hard wired logic with a more generous alarm setting protects the chambers against destruction in case of program failures or other accidents. In this case also an alarm is generated and the powerless open solenoid valves in the distribution rack on top of the electronic trailer connect the chambers with an argon flushed reservoir at atmospheric pressure as indicated in Figure 15. A set of four independent serial links per gas system monitors all gas parameters and distributes this information to the slow control system (see Section 6 of reference [1]).

Gas sensors are distributed in the H1 detector region, on the electronic trailer with the distribution rack and in the volume occupied by the trackers, as well as in the rooms where flammable gases are handled.

The tracker volume is flushed with $\simeq 12$ m^3 of nitrogen gas per hour to prevent accumulation of flammable gases in case of a leak. Since the operational pressure of most chambers is as low as 0.15 hPa relative to atmosphere and only 1.5 hPa in case of CJC, the amount of gas which may escape through a sudden leak in the chamber region is at most only a few liters. Small continuous leaks are best controlled in the closed loop circuits by measuring the pressure drop in the barrel over several days. The maximum working pressure in these circuits is limited to 1.6 bar absolute. A typical leakage of about 4 l/day corresponds to a pressure drop of $\sim$40 hPa/day. In the open circuits additional electronic flow controls, in series with FL1-1 and FL1-2, restrict the input flow. In case of a major leak the operational chamber pressure cannot be reached with the low flux adjusted by these controls.

2.7 Scintillators

Both scintillator arrays discussed in this section are located in the backward region (see Figure 3 of reference [1]) and have been installed to reject proton beam associated background at the first trigger level. The present life time of the stored proton beam in HERA during collisions varies between 10 and 48 h. The stored proton current design value is 160 mA with 2×10^{13} circulating protons in total. These protons are lost by beam gas and beam wall interactions producing background showers of energetic penetrating hadrons and halo muons. With a beam life time of 10 h the H1 sensitive detector volume is hit by this background with a frequency of 2.6 MHz.