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GAS SYSTEM FOR ALEPH TPC

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ABSTRACT

Operation of the Time Projection Chamber of the ALEPH Experiment at LEP requires a high purity argon/methane gas mixture supplied to the detector under stable conditions to ensure minimum signal attenuation throughout the 43 m^3 detector volume (max. 2.2 m drift length) and maintain near-constant electron drift velocity in the gas over extended periods of time. Design considerations for a gas system to fulfil these conditions are presented and details given of the construction, operational aspects and of the achieved performance.

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1. INTRODUCTION

A large Time Projection Chamber (TPC) is used as central detector of the ALEPH Experiment at LEP [1]. The outer cylindrical field cage of the TPC has a diameter of 3.6 m, the inner one of 0.6 m. The axis of the 4.4 m long cylinders is parallel to the magnetic field. Ionization tracks, produced in the gas volume by traversing particles, drift in the electric field created between the central electrode (membrane which divides the detector into two identical parts) and each endplate, where track coordinates, arrival times and ionization loss are measured by a plane of proportional chambers arranged in 2 x 18 sectors with a total of 6336 sense wires, 41004 cathode pads and 1152 trigger pads. The maximum drift distance is 2.2 m. Both field cages are light honeycomb composite structures, representing only 2.3 and 4.8% of a radiation length for inner and outer cylinder, respectively. In order to prevent structural damage of the field cages and to limit deformations of the endplates of 2 x 10 m^2 surface, the TPC operation pressure must be kept within ± 30 mb of the atmospheric pressure.

The TPC performance depends strongly on the gas quality and its long-term stability and on its uniformity over the whole detector volume of 43 m^3. The gas amplification factor and the drift velocity are greatly influenced by changes in the gas mixture ratio. Contamination of the gas by electro–negative impurities causes losses in apparent track ionization due to electron attachment in the drift space, spoiling the dE/dx resolution and also the resolution of coordinate measurements. Extreme care has been taken to minimize these losses. All TPC construction materials that are in contact with the gas (total inner TPC surface is ~ 100 m^2), and all gas system components (total inner surface of more than 300 m^2, including the storage vessels and the connecting tubes) were checked using a special test set-up described in detail in ref. [2]. Only non-contaminating materials and components were accepted for the final assembly. The list of items which had to be rejected was quite impressive [2].

2. SYSTEM DESIGN

The gas system was designed for safe and easy operation with enough built-in flexibility to facilitate various start-up procedures and purges after detector repairs requiring access into the TPC. Important status parameters are permanently monitored and made available to the ALEPH on–line computer system. Hard-wired interlocks prevent dangerous pressure transients, etc. The chosen gas mixture of 91% argon and 9% methane is non–flammable.

The influence of various gas parameters on the detector performance was measured previously in test chambers [3]. Valuable information was collected already in early stages of testing of the "TPC–90", a reduced-scale prototype of the TPC. The results are summarized in Table 1.

TABLE 1

Parameter	Effect on:		
	Attenuation by electron attachment	Max. drift velocity (v_d)	Gas amplif. factor (A)
0.1% ΔCH_4 (absolute)		0.4% at 5.1 cm/s	-2.5% (at $A=10^4$)
10 ppm $O_2(+N_2)$	0.15 – 0.20% per metre of drift	negligible	negligible
10 ppm H_2O	< 0.03% per metre of drift	negligible	negligible
1 mbar Δp			-0.7%

The influence of the gas mixture variations on the resolution of arrival time measurements (z-coordinate) should be kept to 1 x 10^{-3}. That means to achieve at the 9% level a stability of the methane concentration of at least ± 0.03% CH_4. The stability of the mixture over an operation period of several weeks is more important than the precise absolute value of the concentration. The main problem here is that the technically attainable accuracy (stability) in mixing and also in analysis methods is typically worse by almost an order of magnitude. This excludes direct dynamic mixing using mass flow controllers with on-line monitoring and analysis. There are also some important safety considerations for operation in an underground experimental zone, concerning the reliability of interlocks supposed to prevent "excursions" of the mixture into the flammable-gas region. Purchasing large volumes of premixed gas from industry was economically prohibitive (more than 300% higher cost than on-site mixing), because of relatively low average gas consumption.

Premixing of gas into a large buffer volume at moderate pressure was finally chosen as best compromise for the gas system design optimized for maximum long–term stability of the TPC performance. The present variant of the gas system emerged during extensive testing of the TPC prior to final installation in the LEP experimental area. Emphasis has been put on the system reliability. Hard-wired automatic pressure interlocks were used, with latched yes/no response. For the pressure measuring gauges, mechanical instruments (Thommen) with electronic, remotely sensed alarm limits suitable for use in explosive gas atmosphere were chosen, so that most of the important pressure values are indicated and available even during a total power cut. Setting-up, restarting after power failure or high level alarm, periodic supervision and maintenance are carried out manually by dedicated operators. Computer access is restricted to monitoring and diagnostics.

A simplified diagram of the gas system is shown in fig. 1. The full gas system contains about 140 valves of all kinds, 30 pressure indicators and sensors, 4 big pumps, 4 sampling pumps and some 75 alarm and interlock circuits. The bulk of the equipment is localized on the surface above the experimental pit in a building dedicated to gas systems of the various ALEPH sub-detectors. Argon and methane are taken from the common storage at 10 bar pressure and premixed into large steel vessels of 900 m^3 capacity (2 x 70 m^3 at 6.5 bar) which is sufficient for several months of normal operation. Mass flow controllers (Bronkhorst Hi–Tec) are used for dynamic mixing into the vessels at a flow rate of up to 50 m^3/h, under supervision of operators. The mixing ratio is permanently monitored by an infrared absorption analyzer (BINOS; Leybold-Heraeus). Samples of gas could be checked in a mass spectrograph. Pure argon, a reference mixture from a premixed bottle and the previously mixed gas from the buffer vessels are used for calibration to prevent accumulation of systematic drifts or jumps in concentration. With this procedure and in spite of some oscillations caused by the mass flow controller response at each start–up, the mixture reproducibility from batch to batch is better than 0.1% CH_4 (absolute), and variations are further reduced by "dilution" in the big buffer volume. For a typical "fresh gas" flow rate corresponding to ~ 1 TPC volume change per week, the influence of mixture variations on the drift velocity remains negligible.

The gas supply quality (O_2 and H_2O levels, signal attenuation by electron attachment and the gas amplification factor) is systematically checked prior to each buffer refill, using a high resolution 1 m drift chamber set-up, ref. [2], so that any accidental contamination by "dirty" or even "wrong" (different) gas is excluded. Bottles (9 m^3) of methane of 99.95% purity are used. The liquid argon dewar is backed up by batteries of bottles (2 x 120 m^3) of compressed argon gas of 99.995% purity The gas as it enters the buffers from the mixing facility has typically the O_2 level at ~ 1 ppm, the H_2O level below 3 ppm and a residual contamination giving ~ 0.4% loss of signal in 1 m of drift. During tests of the TPC–90 prototype, high grade gas supplied by industry premixed in batteries of bottles was used; the spread in the mixture analysis results as supplied by the company was ± 0.3% absolute. The average contamination in the industrial gas was causing up to 0.8% loss of signal per metre. Individual premixed bottles of the same grade were found to give results comparable to our gas. The mixture from industry contained always an additional strongly temperature–dependent electro–negative impurity. At 26°C (5°C above the operational temperature) the "residual" attenuation was close to 1%. With on site mixing this effect has not been observed.

When the buffer refill is finished, the gas supply is separated from the buffer vessels. The mixture can then be equalized by circulation through both serially connected vessels at a flow rate corresponding to ~ 2 buffer volume changes in 24 hours. A clean, magnetically coupled and pneumatically driven twin-cylinder floating piston pump was developed in–house for this purpose. Fig. 2 shows schematically one cylinder of the pump, with the pneumatic piston driving mechanism omitted. Fine filters (Ultrafilter MF; 99.9999% efficiency at 0.01 microns) are used in the buffer output lines and in the pump output port to remove dust particles which may still be present in the vessels (rust from walls) or which are scraped off from the Teflon seals in the circulation pump.

The buffer pressure (max. 6.5 bar) is reduced in a single stage high precision clean pressure regulator (flow capacity up to 50 m^3/h) to ~ 150 mb, which is low enough for effective use of the buffer volume. Overpressure release valves and a multiple fast-acting interlock chain which closes the line on sudden increase in the downstream pressure prevents propagation of dangerous transients towards the TPC in case of rupture of the pressure regulator membrane, etc. To prevent accumulation of pressure build-ups at high flow rates, the gas feeding line to the underground experimental area is 50 mm in diameter, made of carefully cleaned stainless steel tube welded without seals. The tube length connecting the surface installation to the TPC circulation rack placed on the roof of the underground counting rooms housing the TPC electronics (at a level of ~ 130 m below the surface), is close to 280 m. The circulation rack contains a stainless steel heat exchanger which keeps the gas temperature at 21°C, circulation pump (Rietschle turbine blower), last filtering stage, overpressure interlocks and the "last resort" pressure release devices (bi-directional high flow capacity glass/metal bubblers as shown in fig. 3, containing low–viscosity paraffin oil). About 27 m long, 50 mm in diameter connections to and from the TPC follow a tortuous path along the ALEPH barrel structure and pass through notches towards the TPC supporting feet fixed to the magnet cryostat. The gas is supplied in parallel through both TPC endplates at the bottom and returned from the top of the endplates. The input tubes are thermally insulated.

The TPC central electrode which separates the inner detector volume into two halves is fixed to both field cages leaving narrow but sufficiently "gas transparent" free gaps around both circumferences, so that no pressure gradient between the two half-volumes could be created by eventual (small) differences in flow rates through the two volumes; there is no danger of deformation of the central membrane's flatness (which in turn would affect the drift field uniformity).

The gas return path to the surface is a welded 75 mm diameter clean stainless steel tube. During high flow rate purges, the gas goes directly to an exhaust which is exclusive to the TPC (without no-return flap valve). During ordinary running the gas is passing through a bi-directional bubbler at the surface, which determines the TPC operation pressure together with the weight of the vertical 130 m high gas column.

A purification loop containing a pump (Rietschle turbine blower), Oxisorb (Messer-Griesheim) and molecular sieve could handle up to 2 TPC volume changes per day.

A multiplexed system of two oxygen trace analyzers (Mod. 316, Teledyne Analytical Instruments; ranges 0–10 to 0–10^4 ppm) and a hygrometer (Shaw; range 1–1000 ppm) allows for permanent monitoring of the gas quality at strategic points of the gas system.

3. OPERATIONAL ASPECTS

3.1 Operational pressure

The TPC operational pressure is maintained at 8 to 12 mb above the local barometric pressure in the underground experimental zone and follows the atmospheric pressure variations. The operational pressure includes ~ 5 mb caused by the heavier-than-air column of gas mixture extending to the surface; 3 mb is added in the reference bubbler on the surface; increases are due to flow–dependent pressure build–ups. Hysteresis in the bubbler response and some elasticity of the TPC mechanical structure provoke slow (period of several minutes) relaxation oscillations in the operation pressure, of a magnitude of less than 0.3 mb peak–to–peak. Some additional fluctuations are caused by the forced ventilation of the experimental zone and LEP tunnel (opening and closing of separation doors, etc.).

In the Geneva region, the amplitude of atmospheric pressure variations may exceed 60 mb. Rapid transients during thunderstorms could provoke pressure jumps of several millibars per hour. The fresh gas flow and the bubbler release capacity must be sufficient to follow these changes. The corresponding changes of the drift velocity and of the gas amplification factor could be compensated by automatic adjustment of the TPC drift and signal wire fields.

3.2 TPC flush (purge)

Purging of the TPC is necessary when the detector has been opened for repairs. Purging is also required for the rare case that a certain volume of air has been sucked into the TPC after an extended stoppage of the gas system, caused by the action of an alarm, a power cut, or a malfunctioning, with concurrent rapid increase in the atmospheric pressure. Air contamination is not dangerous for the equipment and entails no safety risk, the mixture being non-flammable.

During purges, the gas mixture entering the TPC at the bottom pushes the air out from the top to the exhaust on the surface. Only very little mixing of air and gas takes place, so that (depending on the duration of exposure of the TPC inner surfaces to air of a given humidity) only ~ 6 TPC volume changes (less than 300 m^3) of gas are sufficient to reach an O_2 level below 10 ppm. This is shown in fig. 4 together with the curve for purge with full mixing, where the O_2 concentration follows the expected $(1 - e^{-n})$ dependence. At a flow rate of ~ 30 m^3/h (1 TPC volume change in 1.5 hours) the TPC overpressure is close to 12 mb. At the underground circulation rack the corresponding pressure in the supply line is approaching 23 mb, with 10 mb in the return. At the surface, the operation pressure reference bubbler is bypassed; the pressure at this point is below 1 mb. The main flow strangulations causing the pressure build-ups are concentrated in the TPC supporting feet and at the passages through the endplate frames. The maximum purge flow rate is limited by a series of overpressure protection devices and bubblers along the circulation path which are set at 35, (±)30, 25, 17 and (±)15 mb. Gas supply valves upstream of all pressure monitoring points are automatically closed and pumps in the corresponding loops are switched off, if the pressure in any particular section of the gas system and/or in the TPC itself is not within operational limits. Reliable pressure interlocks are extremely important, because at the maximum purge flow the pressure in the TPC with the output tubes blocked will increase at a rate of roughly 10 mb per minute, causing irreversible structure damage in less than 10 minutes. Operator presence during purge is required as a supplementary precaution against any risk of failure of pressure interlocks. The relatively high purge flow used is needed in order to be able to restore normal TPC operating conditions, after an intervention inside TPC, in an interval of time compatible with the time required for closing the ALEPH detector and ramping up the magnet. A bypass and a set of TPC separation valves allow for independent purge of the TPC circulation pump loop.

At the flow rate of 30 m^3/h, the gas jets enter the TPC perpendicular to the endplates at a velocity of ~ 4 m/s. However, the speed of the corresponding vertical movement of the gas layer through the central horizontal plane of the TPC is less than 4 cm/min.

3.3 Operation (run)

A fresh gas flow of ~ 4 – 5 l/min (1 TPC volume change in 6 to 7 days) is necessary for maintaining positive overpressure in the TPC in presence of rapid changes in the atmospheric pressure and to compensate for residual leaks around pad connections and seals in the TPC sectors. The speed of the gas movement within the TPC volume is obviously smaller by a factor of 100 with respect to the situation during purge. The full capacity of the premixed buffer storage is sufficient for almost 4 months of continuous operation. For comparison, a single purge consumes the same volume of gas as about 5 weeks of operation. The buffers could be easily refilled during the run (or purge).

3.4 TPC circulation

To avoid the creation of pockets of "stale" gas within the TPC volume, a turbine pump in the underground circulation rack returns the gas from the TPC output to the input via heat exchanger and filter at a flow rate practically identical to the purge flow rate; similar distribution of additional overpressures is produced. As a consequence, operation of the circulation loop is not compatible with high–flow purges and it is inhibited by overpressure interlocks. Turbulences in the circulation turbine cause oscillations in the TPC operational pressure at a level of a few tenths of a millibar, which are superimposed on the (much slower) relaxation oscillations mentioned in sect. 3.1.

3.5 Gas temperature

The temperature of the gas is stabilized at the average ALEPH detector temperature of (21.0 ± 0.5)°C. The cooling loop is over-dimensioned and acts "asymptotically", without regulation. At a flow rate about 50% higher than now used, it could handle temperature differences of up to ± 20°C (too cold or too hot gas from surface storage vessels, exposed to climate variations, during purges; heat generated in the circulation pump). Excessive deviations from the correct temperature of the gas entering the TPC will trigger an alarm and the corresponding interlock will cut the gas supply to the TPC and stop the circulation pump.

3.6 Purification

If necessary, up to two TPC volume changes per day could be purified. Oxygen will be removed by Oxisorb cartridges (capacity 60 litres of O_2; output O_2 level 0.2 ppm). Molecular sieves (cartridge capacity 430 litres) will reduce water vapour to the 1 ppm level at the purifier output. The regeneration of saturated cartridges is done at the factory.

The purification process may also absorb some fraction of residual electro–negative contamination coming from the gas supply or which was liberated from the TPC inner surfaces. Unfortunately, the purifier will inevitably provoke some temperature-dependent variations in the mixture ratio, caused by a selective absorption and re-emission of the mixture components. If needed, the second buffer vessel could be disconnected from the fresh gas storage and used, at atmospheric pressure, in the purification loop to "dilute" the mixture variations in its 70 m^3 volume. This will lead to a loss of 50% in storage buffer autonomy.

It should be understood that the purifier cannot eliminate an effect of a serious leak in the TPC: the TPC performance will be spoiled by uninhibited accumulation of N_2 and the operational overpressure will be gradually lost.

4. MONITORING

Due to the philosophy of the gas system design, only small and slow variations in important gas parameters could possibly appear during normal operation. Some discontinuity in the TPC performance is to be expected only after purges, after restarts following relatively long interruptions of operation and after the start-up of purification. Delicate manipulations and adjustments are performed by specialists. Sudden big leaks, pressure transients caused by the starting up of a high flow pump, etc., are automatically and rapidly handled by pressure interlocks and other alarm systems. Continuous monitoring is essential only for the absolute pressure inside the TPC, ref. [4]. The time constants for "problem propagation" are quite long. Not taking into account the amount of time needed for "transit" through TPC, it takes almost 4 hours (at 5 l/min) for the first indication of e.g. an increase in the O_2 level to appear on the surface (the parasitic volume in the return path is > 1 m^3). Using small diameter monitoring tubes in parallel allows to reduce the propagation time to < 20 minutes at 1 l/min.

While for safety reasons it was preferred to resort to hardwired automatic pressure interlocks from mechanical instrumentation for fast response, emphasis for monitoring and diagnosis of the gas system status was put on remote information access via the ALEPH on–line VAX computer cluster. This allows continuous monitoring and logging of the gas parameters required for the data evaluation from experimental runs (absolute pressure and temperature of gas in TPC, etc.) and of any fault conditions, and at the same time allows checks of the gas system status to be made from the main CERN site, which is at a considerable distance from the ALEPH Experiment.

The gas monitoring tasks run in the framework of the TPC Slow Control system [5]. This uses front–end monitoring and control crates (MAC–64) based on the Motorola M6809 processor with G–64 backplane bus and connected to a Utinet local area network. The network is in turn attached via a gateway through Ethernet to the ALEPH cluster.

Two MAC–64 crates on the same local area network are used for the gas system, one in the surface gas building, the other in the underground area. Status and alarm bit information is entered via five 32 bit input cards. At present some 150 status information bits are connected. These include alarm bits for pressures, gas–leaks, temperatures; positions of valves, enabling keys, pumps on/off, position of multiple switches, etc. Analog information is entered via two 16 channel 12 bit resolution ADC cards. The accessible data include gas flow rates, temperatures, overpressures, etc., as well as the absolute pressure inside TPC. A second absolute TPC pressure reading is entered in parallel binary coded decimal form. Further input/output cards to steer two pulse height analyzers (for use with the 1 m high–resolution drift chamber) are included as well as, for future development of automatic restart procedures, a limited signal output capacity. All the mentioned information is readily available remotely and in easily readable form via a menu–driven gas system monitoring program.

Due to the special importance of the absolute pressure (and to a lesser extent the temperature) inside TPC for the evaluation of track ionization, an extra pressure transducer with a direct readout from the VAX cluster via a CAMAC interface, independent of the local area network, has been incorporated. This chain includes the readout of a set of 4 temperature sensors which protrude into the TPC gas volume through the endplates, near the top and the bottom of the volume.

The best real–time monitoring method for the detector performance (drift velocity; gas gain; attenuation; uniformity of response) is clearly the continuous use of particle and laser beam tracks from the TPC itself.

5. PERFORMANCE

The leak rate of the completed TPC is of the order of 1 l/min per endplate, at the nominal operational pressure. It seems to be caused mostly by residual tiny leaks around some of the pad feedthroughs in the detector sectors. Individual leaks of this size are extremely difficult to localize, because the heavier-than-air mixture "rains" down along the vertical large area TPC endplates. Access around the preamplifier cards and cables is not easy.

As shown in fig. 5, we have in the TPC (in the "equilibrium state", several weeks after end of purge) at 5 l/min of fresh gas flow and without purification the O_2 level at ≤ 20 ppm. The corresponding H_2O level depends strongly on the exposure to humidity during the last "TPC open" period. One week after purge it is typically ~ 30 – 40 ppm and it will then slowly decrease to 15 – 20 ppm. These values include the contribution from the installation in the gas building (storage) and from the tubes going from the surface to the experimental zone and back, plus the residuals from the gas supply and from the gas system components, which represent together less than 3 and 5 ppm of O_2 and H_2O, respectively. The above mentioned levels of oxygen and water vapour in the TPC will cause less than 0.5% loss of signal per metre of drift. The residual contamination of the gas supply and of the gas system itself contributes an additional 0.5% to this, including systematic effects and attenuation measurement errors. The contamination of the TPC inner surfaces (sectors) gives ~ 0.5%, leading to a total of $\leq 1.5\%$ loss per metre of drift by electron attachment. This is a conservative value which should slightly improve with running time. To our knowledge, such a low attenuation has not been achieved elsewhere. The next best results (about 6% signal loss per metre in PEP–4 [6] and TOPAZ [7] TPC's) were obtained only under permanent purification and at high flow rates corresponding to several detector volume changes per day. In our case, some improvement may still be obtained by reducing the oxygen contribution (0.3% attenuation) by purification at a rate of e.g. 30 l/min (1 TPC volume change per day). Water vapour level is already comfortably low and its influence practically negligible, so that the use of molecular sieve is not necessary. The danger of mixture variations introduced by the purification process were already discussed in sect. 3.6. Periodic regenerations of spent Oxisorb cartridges would cause a non–negligible increase in the running cost.

We found that it is fully sufficient to check the attenuation after every purge and then only at several week intervals, using the 1 m drift high–resolution monitor chamber. Accidental contamination of the "open" TPC by strongly electro–negative agents must be prevented. Use of Freon (or other organic solvents) for cleaning is forbidden in the vicinity of the TPC endplates. Halon in (automatic) fire extinguishers represents a certain danger of contamination in case of a spurious fire alarm generated during the interval of time when the TPC is open for repairs. For the same reason, halon was replaced by CO_2 for injection into the gaps (inerting) between individual sub-detectors.

The TPC performance and the main gas system parameters are summarized in Table 2.

TABLE 2

Gas mixture:	91% Ar + 9% CH_4 (non-flammable)
Mixing:	Dynamic by mass flowmeters into large buffer volume
Abs. precision:	$(9.0 \pm 0.3)\%$ CH_4
Monitoring/analysis:	IR absorption; resol. 0.1% (abs.) (checks: mass spectrometer)
Calibration:	Pure Ar; premixed reference bottle; "old" gas from buffers
Long–term stability:	~ 0.03% CH_4 (absolute) per week
Purity of gas to TPC:	$O_2 < 3$ ppm; $H_2O < 5$ ppm; attenuation: ~ 0.5% /m of drift
Flow rates:	– Fresh gas: minimum 4 litres/min (1 TPC volume /week) – Buffer filling: 50 m^3/h – TPC purge: 30 m^3/h (1 TPC volume in 1.5 h; 6 TPC volume changes needed) – TPC circulation: 30 m^3/h
Purifier:	– Flow: Up to 3.5 m3/h (2 TPC volume changes per day) – Output: $O_2 < 0.2$ ppm (Oxisorb capacity 60 litres) $H_2O \sim 1$ ppm (molecular sieve; capacity 430 litres)
Buffer volume:	900 m^3 (2 x 70 m^3 at 6.5 bar)
Autonomy:	Up to 4 months (without purges)
TPC overpressure:	8 to 12 mb above local atmospheric pressure; oscillations ≈ 0.3 mb
Gas temperature:	(21.0 ± 0.5)°C at maximum flow rate, no regulation (determined from cooling water temperature)
TPC performance:	– Fresh gas flow 5 litres/min, without purification: $O_2 \approx 20$ ppm; $H_2O \approx 20$ ppm; – Signal attenuation: $\leq 1.5\%$ /m of drift

6. CONCLUSIONS

The TPC gas system design has allowed to reach excellent long-term stability of all important gas parameters affecting the TPC performance. Manual restart required after power cuts (alarms) was found to represent a highly desirable additional safety precaution, limiting dangers of structural damage to the fragile TPC structure.

A remarkably low loss of signal by electron attachment of ≤ 1.5% per metre of drift was achieved in the 43 m^3 volume of the TPC, for a fresh gas flow rate corresponding to about 1 detector volume change per week, without purification. Water vapour influence was found to be negligible at typical operational levels. As a consequence, systematic use of the available purification facility is not considered to be of vital importance, especially due to a risk of purifier-induced mixture variations.

The fresh gas flow rate was determined essentially by the residual TPC leaks. If desired and economically acceptable, the flow could be doubled to 10 l/min, which in turn will reduce the attenuation due to oxygen and other residual contamination in the gas towards a total of ~ 1% loss per metre of drift. The buffer autonomy would go down to about 2 months, which is still more than adequate.

For the running–cost considerations it is interesting to note that (depending on the frequency of necessary purges) the use of gaseous argon from batteries of bottles may still be economically more attractive than the use of liquid argon from a dewar dimensioned for too much reserve capacity. Since the start of the TPC tests (end 1986), about 12000 m^3 of gas were mixed and used in our facility.

Due to the gas system design flexibility it will be not too difficult to incorporate demands for future gas system development and upgrading, which may ask for a certain degree of simplification of operation, more active computer access, introduction of fully automatic restart procedures, modifications required if different gas mixture (neon) will be envisaged, etc.

The use of non-flammable methane mixture removes most of the safety related problems concerning the TPC operation in the underground experimental area. However, more care must be taken in the gas building at the surface, to prevent dangerous consequences (suffocation) of an accidental massive rapid discharge of the mixture from the buffer vessels into the TPC gas mixing room. Two independent gas leak detection systems are provided, backed-up by permanent monitoring of oxygen level. High-level alarms will close the gas supply valves and double the speed of the permanent forced ventilation in the building.

REFERENCES

[1] ALEPH Handbook, W. Blum editor, CERN/ALEPH 89-77 (1989).

[2] I. Lehraus et al., CERN/EF 89-8 (ALEPH 89-89) (1989).

[3] I. Lehraus et al., CERN/ALEPH-TPC 84-6 (1984).

[4] I. Lehraus et al., CERN/ALEPH-TPC 83-30 (1983).

[5] J.M. Maugain et al., CERN/ALEPH 88-36 (1988);

[6] H. Aihara et al, IEEE Trans. Nucl. Sci., Vol. NS-30 (1983), No. 1, 65.

[7] A. Shirahashi et al., IEEE Trans. Nucl. Sci., Vol. NS-35 (1988),No. 1, 414.

FIGURE CAPTIONS

Fig. 1	Simplified diagram of the TPC gas system.
Fig. 2	High pressure clean circulation pump.
Fig. 3	Bi-directional high flow capacity bubbler.
Fig. 4	Reduction of oxygen concentration during purges.
Fig. 5	TPC and gas system performance.

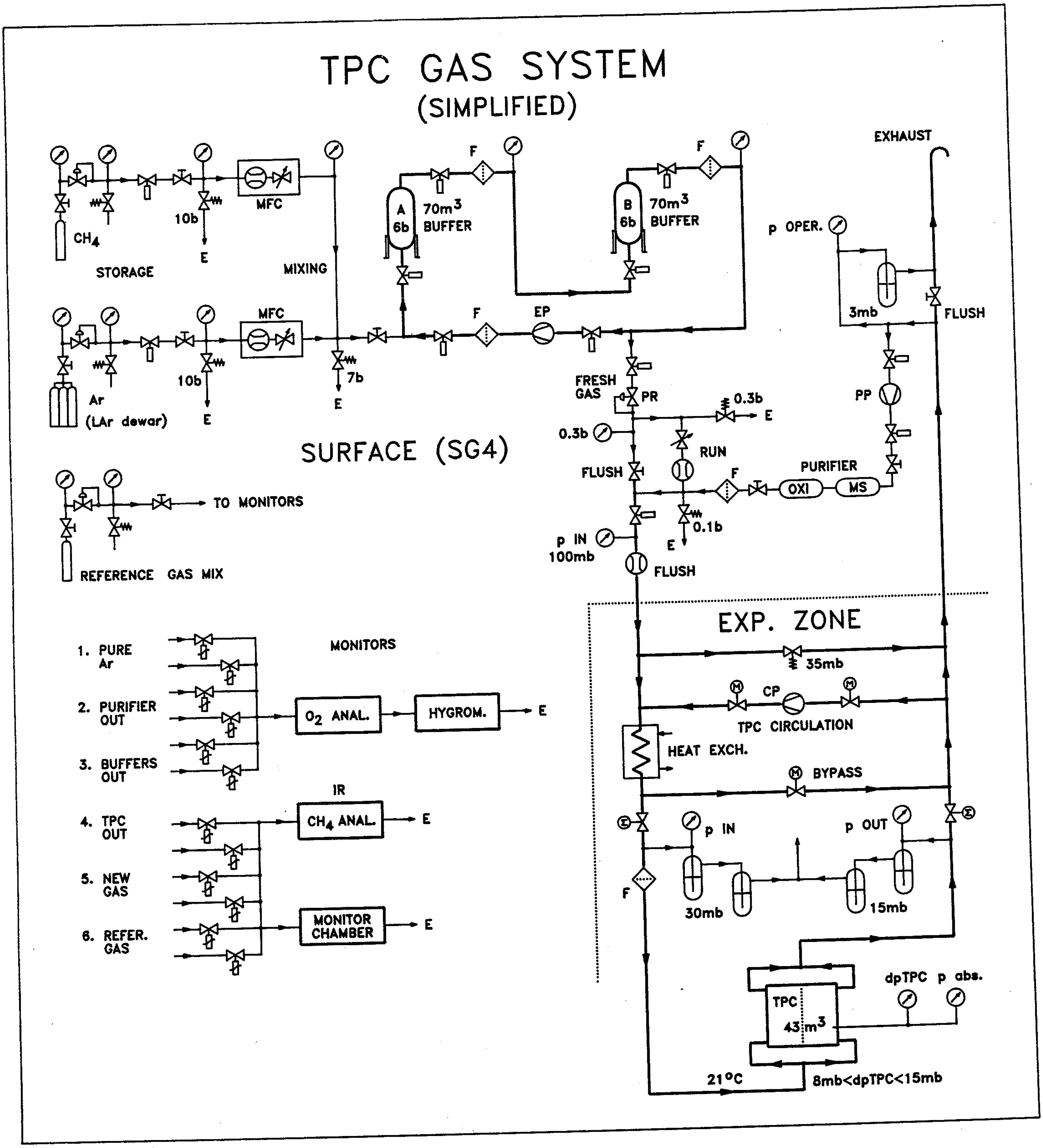
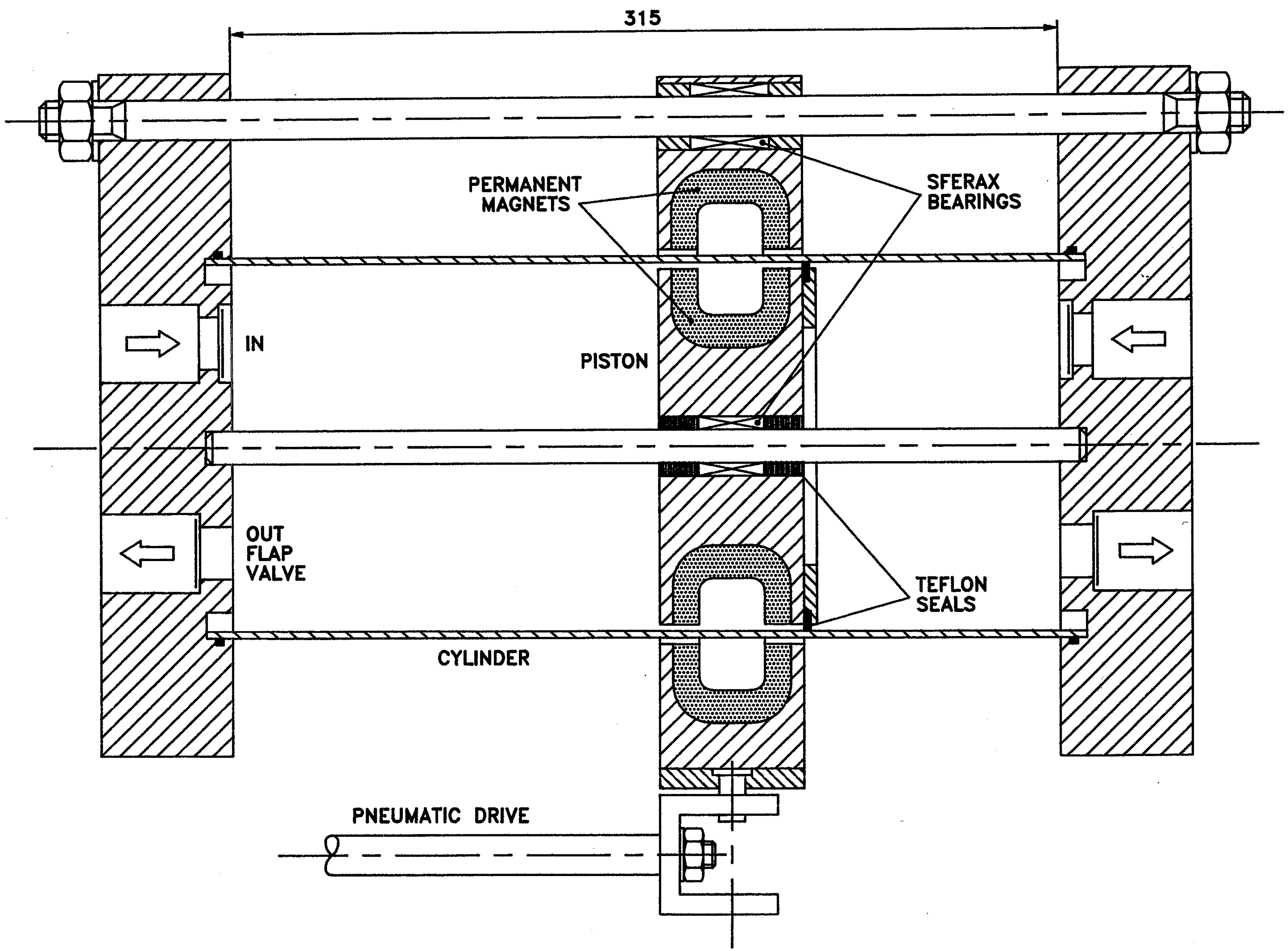

TPC GAS SYSTEM
(SIMPLIFIED)
CH$_4$
STORAGE
10b
E
MFC
MIXING
F
A
6b
70m^3
BUFFER
B
6b
70m^3
BUFFER
EXHAUST
p OPER.
3mb
FLUSH
Ar
(LAr dewar)
10b
E
MFC
7b
E
F
EP
FRESH
GAS
PR
0.3b
E
0.3b
RUN
PP
PURIFIER
OXI
MS
F
FLUSH
0.1b
E
p IN
100mb
FLUSH
SURFACE (SG4)
TO MONITORS
REFERENCE GAS MIX
EXP. ZONE
35mb
CP
TPC CIRCULATION
HEAT EXCH.
BYPASS
p IN
p OUT
30mb
15mb
F
TPC
43 m^3
dpTPC
p abs.
21°C
8mb<dpTPC<15mb
MONITORS
1. PURE Ar
2. PURIFIER OUT
3. BUFFERS OUT
O$_2$ ANAL.
HYGROM.
E
IR
4. TPC OUT
5. NEW GAS
6. REFER. GAS
CH$_4$ ANAL.
E
MONITOR CHAMBER
E

Fig. 1


315
PERMANENT MAGNETS
SFERAX BEARINGS
IN
PISTON
OUT FLAP VALVE
TEFLON SEALS
CYLINDER
PNEUMATIC DRIVE

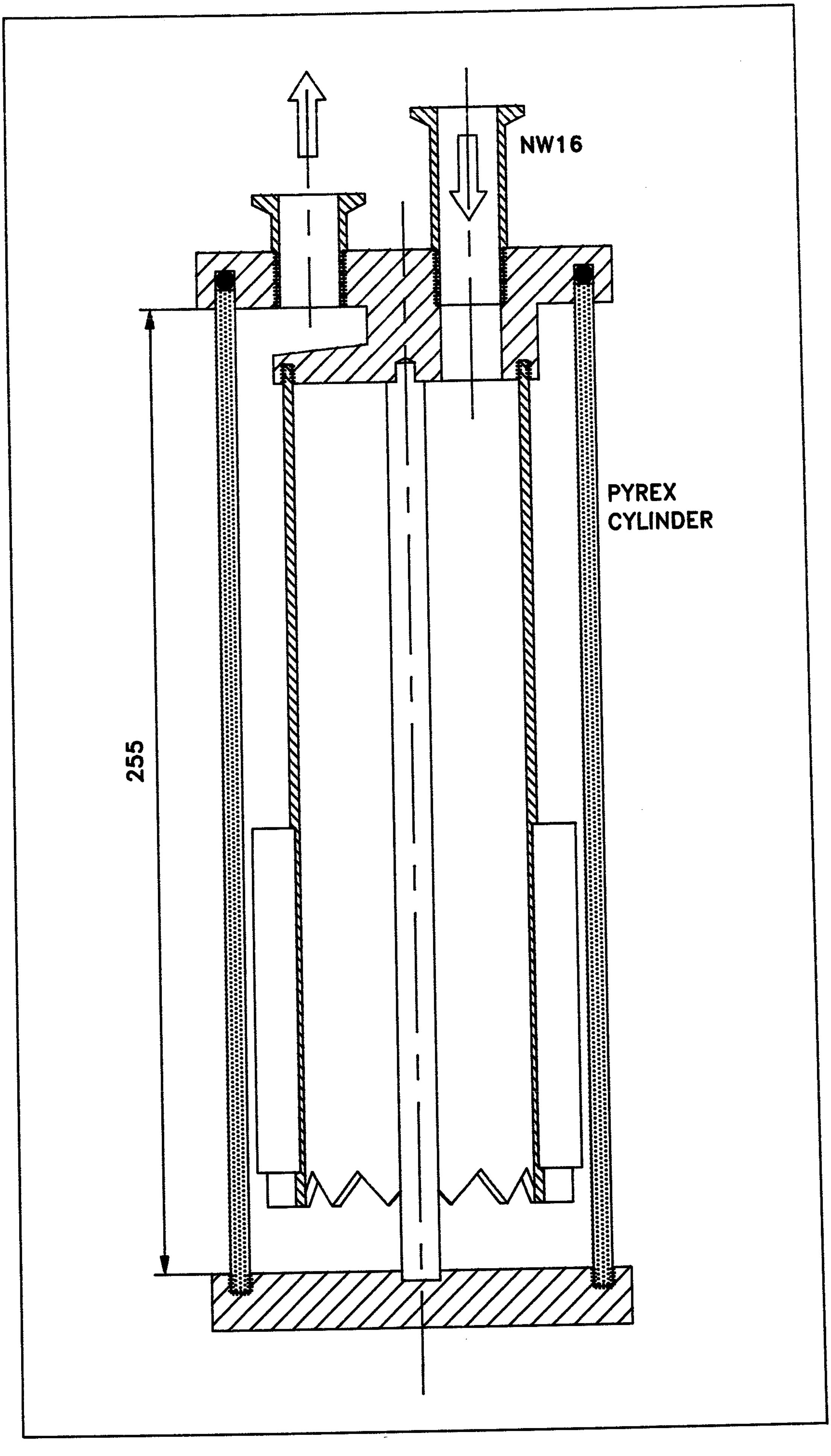


Fig. 3

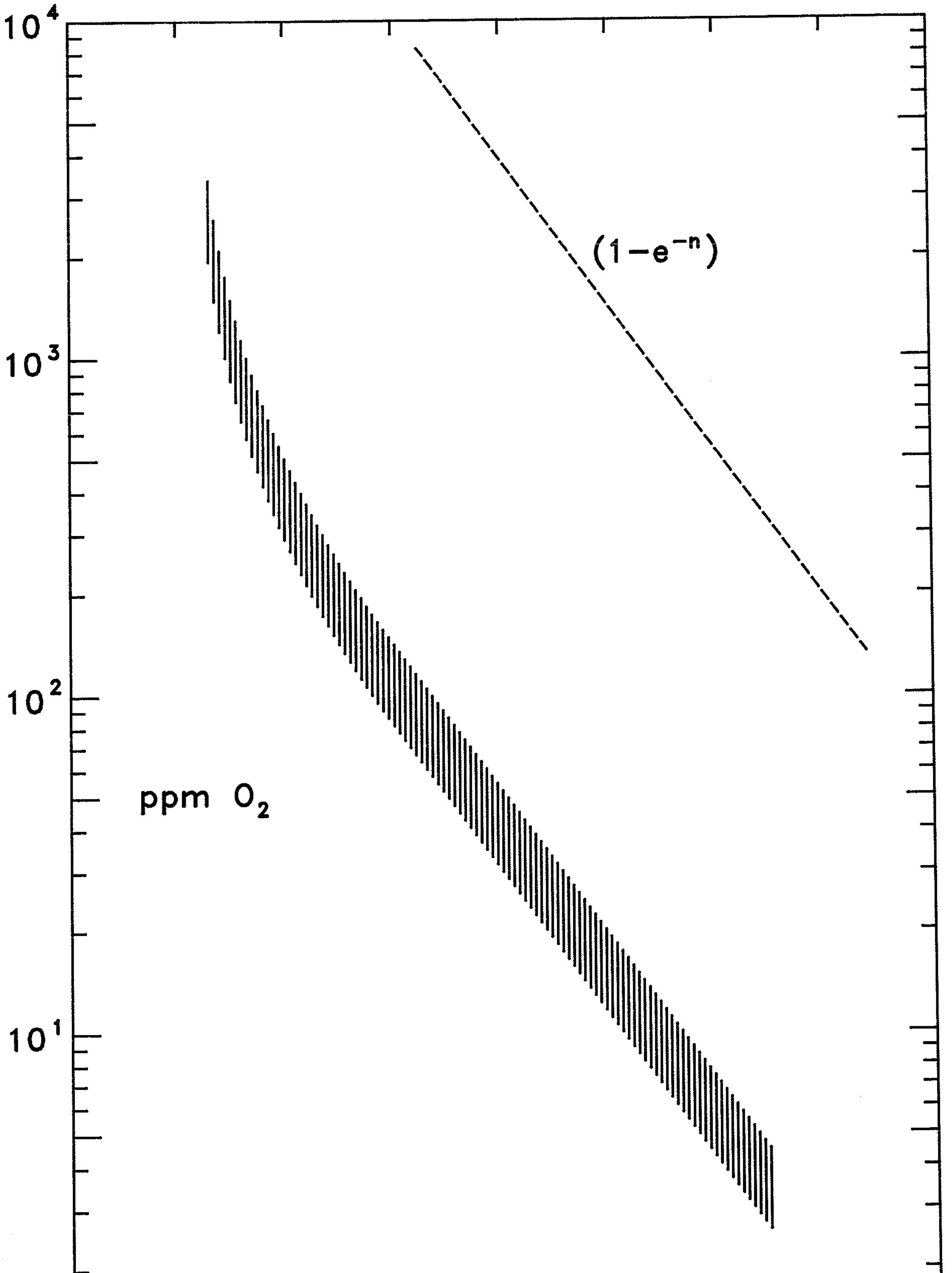


Fig. 4

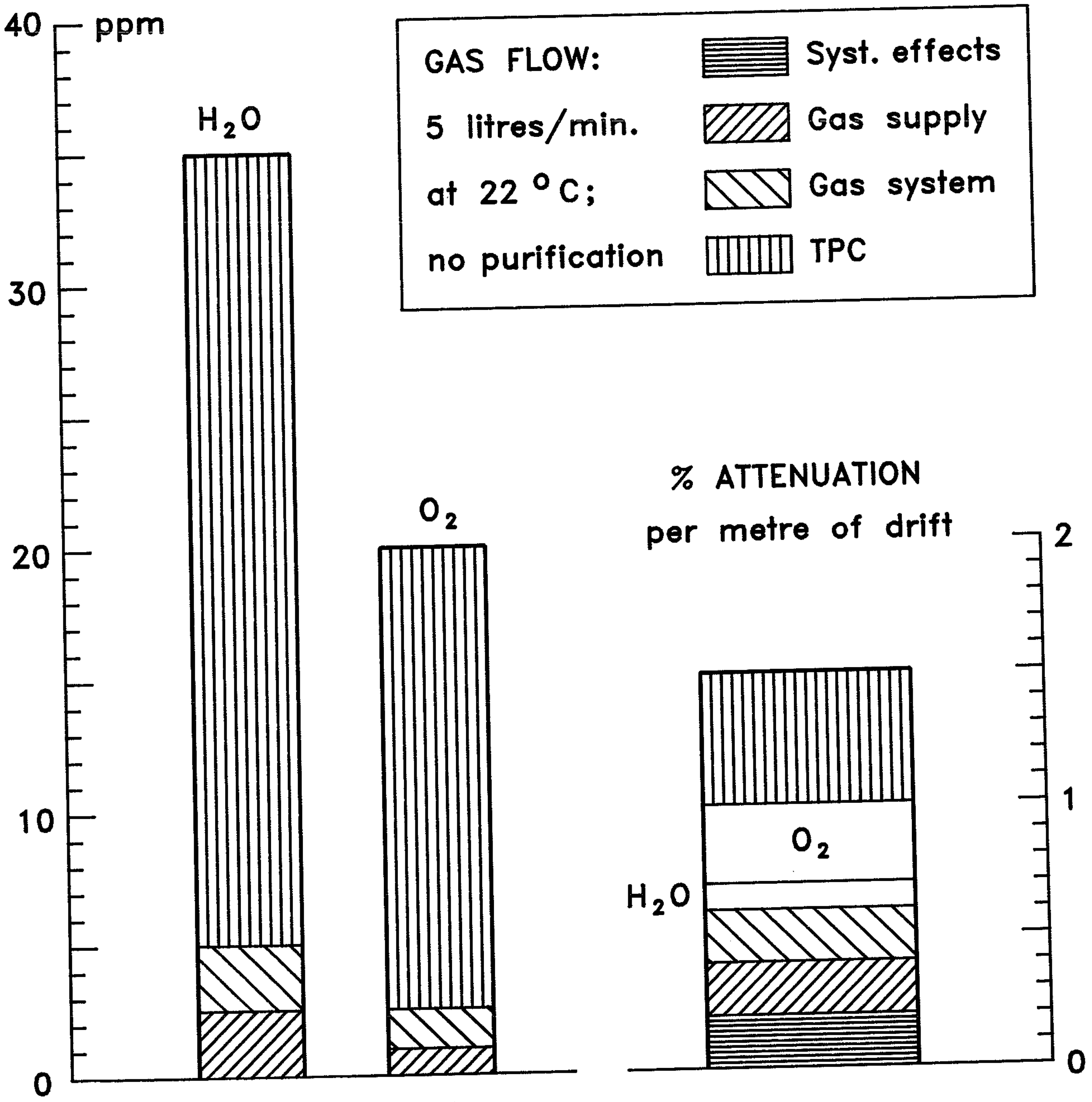

40
ppm
30
20
10
0
H_2O
O_2
GAS FLOW:
5 litres/min.
at 22 °C;
no purification
Syst. effects
Gas supply
Gas system
TPC
% ATTENUATION
per metre of drift
2
1
0
O_2
H_2O

Fig. 5

TPC GAS SYSTEM

(SIMPLIFIED)