AN IMPROVED SULPHUR HEXAFLUORIDE GAS HANDLING SYSTEM FOR A POTENTIAL DROP PARTICAL ACCELERATOR

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SUMMARY

An improved sulphur hexafloride (SF_6) gas handling system has been designed and built for the Lewis Research Center 3.0 Mev Dynamitron Accelerator utilizing the original components provided with the accelerator. The purpose of the system is to remove the gas from the accelerator when opening is necessary, purify and store it, and return it to the vessel. The advantages are; reduction in cycle time from 7 hours to about 3 hours, reduction in unretrieved gas from 7% to as little as 0.02%, compactness and improved purification resulting from liquefaction and additional filtering, and safe, reliable semiautomatic operation. Design considerations, fabrication techniques, and performance evaluation of the system are given.

INTRODUCTION

The basic function of a gas handling or recovery system is to reclaim the insulating gas in an accelerator vessel, purify and store it until the internal modifications have been completed, evacuate the air from the vessel and then recharge it with the insulating gas, in a minimum time. From a practical point of view it is very desirable that the cycle time be a small fraction of a working shift so that the trouble can be diagnosed and corrective measures taken which take advantage of overnight procurement and/or fabrication services.

The advantages of using SF_6 as an insulating gas for potential drop machines have been previously discussed in the literature.[2,3,4] Briefly, these advantages include; lower gas pressure may be used than with the more common N_2-CO_2 mixture to achieve the same dielectric strength, good heat transfer for cooling, chemical inertness, minimal toxicity, and self-healing breakdown products. However, the cost of an SF_6 gas load is an order of magnitude higher than an N_2-CO_2 gas load. This requires that special consideration be given to efficient recovery and reuse of the gas and to the rate of accumulation of impurities.

The performance data for SF_6 recovery systems for large[2] and small[5] volume accelerator vessels are available. Discarding the original system was considered. However, for economical reasons, it was decided to design an improved system which utilizes the major components of the rather slow and inefficient recovery system provided with the Lewis Research Center Dynamitron. The performance of the improved system compares favorably with the above mentioned systems[2,5] and in addition has certain unique features. Since our situation is typical, it was felt that other laboratories possessing or anticipating an accelerator installation might benefit from our experience.

DESIGN CONSIDERATIONS

The original recovery system supplied with the Dynamitron consisted of a Corken Model 390 compressor (15 ft^3/min) which liquified the gas and returned it through a Sperlan type C-966-P chemical and mechanical filter and an 18-port manifold to the shipping cylinders. Recharging the vessel was accomplished by pressure equalization between the cylinders and the vessel, and was limited to a rate such that the cylinders were not allowed to cool down to the brittle fracture temperature range (i.e., about 0°C).

The vapor pressure[6] of SF_6 at 20°C is 305 psig. The specific volume of SF_6 under the prevailing conditions is 0.35 ft^3/lb according to the information supplied by the Allied Chemical Company.[6] Therefore the gas load is computed to be 1500 lb for a total system volume of 525 ft^3. For our system this corresponded approximately to 6 psi increments per 100 lb of SF_6.

Typical operation times for the various phases of the original system are shown in Table 1. It is seen that 1/2 atmosphere of SF_6 remains in the vessel after the liquefaction phase which means that over 100 lb of SF_6 is unretrieved in each cycle. Assuming 12 vessel openings per year, this amounts to an annual loss of about $2400.00.

From the viewpoint of faster cycle time, Table 1. also shows that the best potential for improvement in cycle time is in the pressurization and recovery phases. The pressurization rate can approach the flow limitations of the interconnecting pipe provided additional thermal heat capacity and/or wider operating temperature range is incorporated in the hardware so that the brittle fracture temperature is not reached. Improvements in the recovery phase can be accomplished by using a larger storage vessel and high speed nonliquifying compressors so that the SF_6 is stored as a gas. Alternatively this can also be accomplished by adding more liquifying capacity. The latter approach was adopted not only to take advantage of the equipment available but also to conveniently provide a means for removing the noncondensible impurity buildup by the method described by Ashbaugh, et al.[2]

Based on these considerations, an improved SF_6 recovery system was designed which has the

capabilities shown in Table 1. It can be seen that essentially all the SF_6 is recovered (gas remaining in the accelerator vessel is 0.02%. Moreover the cycle time has been reduced to less than 3 hours.

In the improved system, liquefaction is accomplished by two 15 ft^3/min compressors working in parallel. Below atmospheric pressure in vessel the pumping speed of the compressors is considerably decreased. At this point, an 80 ft^3/min vacuum pump is switched in series with the compressors to maintain their inlet pressure slightly above atmospheric and evacuate the remainder of the gas in the accelerator vessel. The liquified gas is stored in two laminated steel tanks, each of which is 2 ft ID x 16 ft L, weighs 5800 lb, has a capacity of 50 ft^3, and is rated for 2800 psi between ±40°C. The tanks are mounted horizontally so that during the pressurization phase evaporation takes place over a large surface area and the heat is extracted more uniformly from the remaining liquid and the tanks. Because of the additional volume of these tanks compared to the original system, the total SF_6 gas load for the system is now 1800 lb. When the tanks are fully charged, they are about 1/4 full. The heat of vaporization of SF_6 at 20°C is 15.5 cal/g[6] which corresponds to 14.3 kWh (49,300 Btu) for 1800 lb of SF_6. If we assume that this heat is supplied during the pressurization phase by the heat capacity of the storage vessels only (zero transfer time) and further restrict the temperature of the storage vessels to a lower limit of 0°C (ΔT = 20°C), computation indicates that 13.8 kWh are available from them. To provide an additional margin of safety the temperature of the storage vessels is raised to 30°C prior to pressurization to reduce the heat of vaporization to 11.8 cal/g[6] while only raising the vapor pressure in the storage vessels to 415 psig. This technique reduces the required heat of vaporization to 11.0 kWh and raises the available heat capacity to 20.7 kWh (approximately).

At present, we have encountered no problem from buildup of noncondensibles. The major source of noncondensibles is the residual air in the accelerator vessel (500 microns) prior to pressurization which corresponds to an increment of about 0.01% noncondensibles per cycle. At this rate we would not anticipate any serious problem from the accumulation of noncondensibles even if it were a leak-tight system. Leakage of SF_6 from the normally pressurized accelerator vessel corresponds to about 25 lb per week (three times lower than originally) despite our considerable efforts to detect and correct leaks. Based on one cycle per month, and the above leak rates an equilibrium calculation shows that the upper limit of noncondensible impurities concentration is 0.2%.

Improved Gas Handling System

A simplified layout of the improved gas handling system built for the LeRC Dynamitron is shown in Fig. 1. All the components except the storage tanks are in the accelerator vault and are mounted on a raised platform to conserve floor space and take the advantage of the high overhead clearance required for the vertically mounted Dynamitron. The storage tanks are mounted in an airconditioned shed immediately adjacent to the accelerator vault. The main interconnecting pipes are 2 inch welded stainless steel with nonrestricting valves. The primary system functions are manually or push-button operated to provide flexibility in cycling. With further operating experience part or all of the system may be automated if this proves desirable. The high pressure section of the system has been pressure checked to 750 psig which is well above the highest relief valve setting of 325 psig on the storage vessels.

Referring to Fig. 1, the operation of the gas handling system for the liquefaction, evacuation and pressurization phases can be readily followed. During liquefaction, the gas is pumped from the accelerator vessel to the storage tanks, passing through the ballast tank (10 ft^3), the liquefiers, the scrubber and the filter (F_1). The scrubber is a heavy duty unit consisting of a molecular sieve, soda lime (Na OH + CaO) and activated alumina (specially dried Al_2O_3) while F_1 contains soda lime and activated alumina for a final cleanup. An additional pipe line and valve from the storage tank permits storage in the shipping cylinders or for additions to the gas load. When the accelerator pressure drops below 0 psig the flow is diverted through the vacuum pump to maintain the inlet pressure to the liquefiers near atmospheric. The pressure activated valve in the vacuum pump inlet line prevents it from experiencing pressures above atmospheric in case the vacuum pump were switched on line too soon. The 3 psig relief valve vents any trapped gases. The two solenoid valves on the vacuum pump outlet are electrically wired so that one is open when the other is closed to positively separate their functions in the liquefaction and evacuation phases. The vacuum pump outlet relief valve is set for 5 psig to protect the vacuum pump. During the liquefaction phase, the vacuum pump inlet is throttled until the accelerator vessel pressure reaches 7.5 psia to match the pumping speeds of the vacuum pump and the liquefiers and prevent any loss of gas through the relief valve. During the evacuation phase, the vacuum pump is vented directly outside through the mist eliminator which prevents gross loss of pump oil. During this phase, it has been found that a dry ice-acetone cold trap improves the useful working life of the vacuum pump oil charge which would otherwise rapidly contaminate due to high local humidity conditions. During the pressurization phase, the gas passes from the storage tanks through the particulate filter (F_2) to the accelerator vessel. This line passes through the base of the vessel and therefore is not removed for normal vessel disassembly. It is fitted with a baffle inside the accelerator vessel so that the high velocity gas stream does not blow directly at the accelerator components.

Appraisal

Tangible economic benefits from this system include complete gas recovery and 4 h less shut-

down time for each cycle. Placing a reasonable value on these items, and assuming 12 cycles per year, the capital cost of the system is expected to be recovered in about 2 years.

References

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TABLE I. COMPARISON OF OPERATION PHASE TIMES FOR THE ORIGINAL AND IMPROVED SF_6 GAS HANDLING SYSTEM

Operation phase	Original system			Improved system		
	Vessel pressure		Elapsed time	Vessel pressure		Elapsed time
	Initial	Final		Initial	Final	
1a. Recover SF_6 from accelerator using liquefiers only	85 psig 0 psig	0 psig 7.5psia	155 min 60 min	85 psig	0 psig	60 min
1b. Recover SF_6 from accelerator using liquefiers and vacuum pump	-------	------	-------	0 psig	1000 μ	35 min
2. Admit air to accelerator	7.5 psia	0 psig	5 min	1000 μ	0 psig	5 min
3. Evacuate air from accelerator	0 psig	500 μ	60 min	0 psig	500 μ	45 min
4. Pressurize accelerator with SF_6 (self-transfer)	500 μ	85 psig	120 min	500 μ	85 psig	30 min
TOTALS			6 h, 40 min			2 h, 55 min

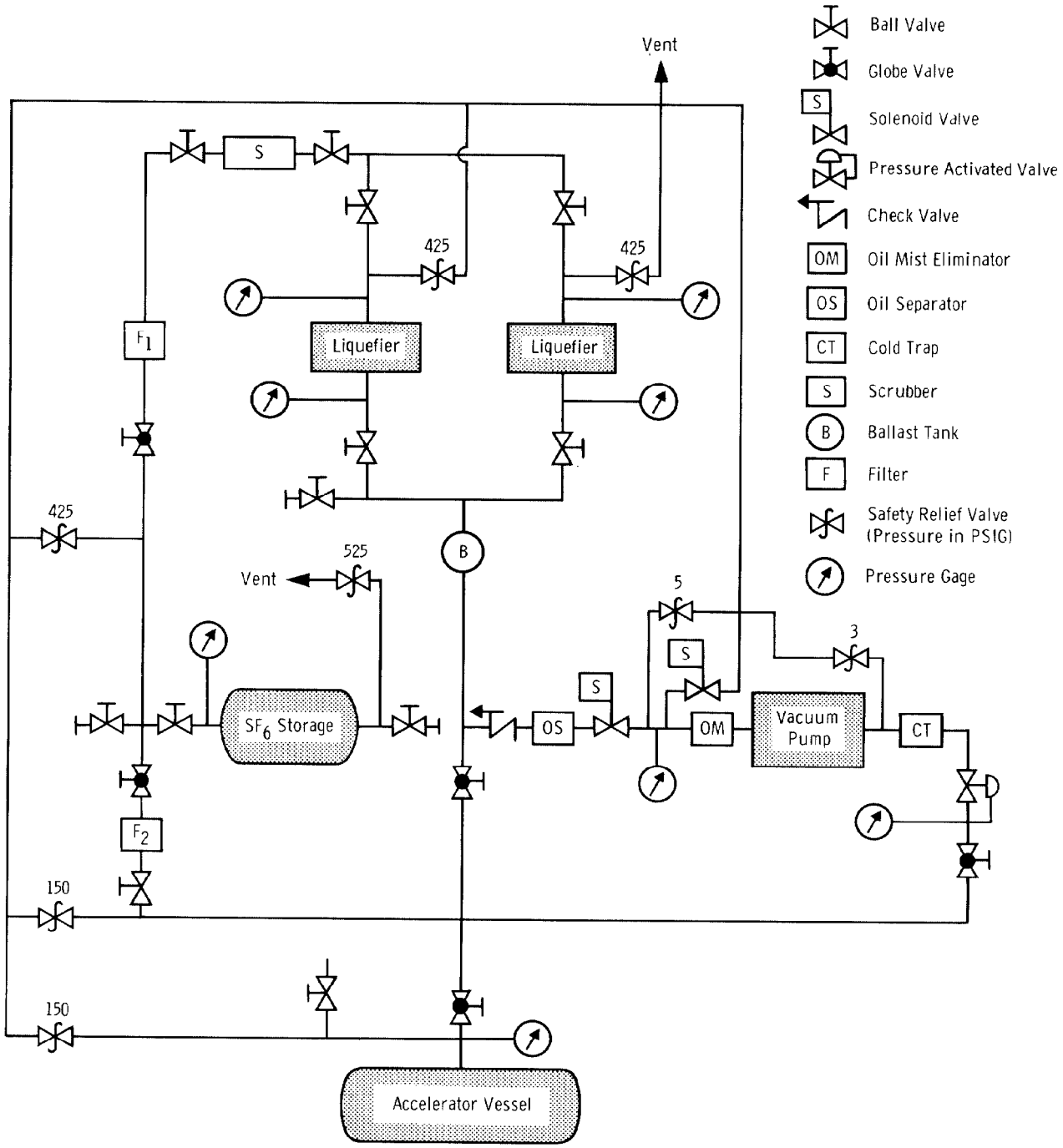

Fig. 1. LeRC Dynamitron Accelerator SF_6 Gas Handling System.