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APPLICATION OF QUALITY ASSURANCE GUIDELINES TO THE HIGH PRESSURE GAS
SYSTEM, BUILDING 331

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MASTER

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APPLICATION OF QUALITY ASSURANCE GUIDELINES TO THE HIGH PRESSURE
GAS SYSTEM, BUILDING 331

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ABSTRACT

Major improvements have been made to decrease the tritium release potential for LLL's tritium-handling facilities in Bldg. 331. This report describes some of the major problems and solutions in designing and building the High Pressure Gas System, which was the first system to be rebuilt. To increase system safety, it was necessary to specify material and processes used in component manufacture, to inspect all materials and processes to ensure compliance with specifications, to use proper joint design, to use secondary containment in cases where specifications could not be met, and to exercise tighter control of operating procedures.

INTRODUCTION

The updated High Pressure Gas System, in operation since July 1975, is the LLL facility used in filling pressure vessels with tritium. It has the capability of compressing 125 g of tritium from 55 kPa (8 psia) to 1.03×10^5 kPa (15 000 psia). It can also provide gas mixtures to 1.72×10^5 kPa (25 000 psia). Reference 1 gives a more detailed description of the system; drawing AAA 71-110536-OF is a schematic that gives an overall perspective.

The system as it exists today is the result of a review and updating that started about five years ago. In 1970 a major release of tritium occurred from one of the tritium systems in Bldg. 331. As a result, all systems in the building were reviewed to determine what actions were necessary to minimize the release potential. The High Pressure Gas System was the first to be reviewed because it has the highest pressures and the largest quantities of tritium in the building.

Originally, air flush hoods were used in Bldg. 331 to protect operating personnel. In the event of a tritium leak, the air flushes the tritium away from the personnel and up a tall exhaust stack, which helps disperse the tritium before it settles to the ground. The hoods with their sliding doors provide a maximum of convenience to the operators.

After 1970, methods of containing tritium — e.g., glove box containment, a plant to process all the air exhausted up the stacks — were considered of prime importance. However, any of the methods either added to the inconvenience of operation or had a significant cost. It was therefore decided to review the failures causing tritium releases and take corrective action to prevent those types of failures.

Previous releases resulted from (1) the failure of metal seals made of material unsuitable for hydrogen service, (2) transducer and pressure gage failures, (3) leaking mechanical fittings, or (4) operator error — loosening a leaking fitting instead of tightening it, for example. These failures fall into three categories: (1) material selection — metal seal failure, transducer and pressure gage failure, (2) joint design — leaky fittings, and (3) operator error — opening wrong valves or attempting to tighten a fitting under pressure.

To prevent these failures and thereby improve the safety of a tritium-handling system, the following must be done:

1. Specify the correct material for the system components
2. Specify the correct manufacturing and assembly processes for the equipment
3. Inspect and test all materials and processes to ensure that specifications were followed
4. Use proper joint design
5. Use secondary containment for items that cannot meet the preceding requirements
6. Exercise tighter control of operating procedures

By taking action in all six of these areas, we were able to improve the safety of the High Pressure Gas System. The remainder of this report gives the details of each category.

MATERIAL SELECTION

The principal material chosen for the construction of the systems was AISI stainless steel 316. It was selected because it is a stable austenitic steel, weldable, resistant to hydrogen embrittlement, and not subject to gross martensitic transformation when thermally cycled or plastically strained at cryogenic temperatures. The high quality nuclear grade material with the cleanliness and chemistry we require is available directly from the steel mills.

Using stainless steel 316 created several problems. First, because it must be purchased directly from the mills, it must be ordered in minimum lots of 5000 lb (2268 kg), with a minimum order of 500 lb (227 kg) for each size or shape within the order. Second, the lead time to get the material from the mill is six months to a year. Third, vendors of system components are reluctant to use our material because our orders are too small. The vendors do not want to buy a mill quantity of steel; further, they do not want to be bothered with our certification and quality assurance requirements.

To solve these problems we created a certified-material storeroom. The storeroom serves all the tritium-handling systems and can therefore buy the mill quantity steel. Vendors draw on these supplies to make system components. The storeroom also stocks components that are common to several systems (e.g., tubing, valves, fittings) and bars and billets from which specialty items can be made. As a result, lead time on component delivery can be reduced by as much as two years.

All items in the certified-material storeroom have been made and inspected to rigid specifications. For more details about components in stock, see the appendix.

The certified-material storeroom has generally solved our materials problems. However, if a vendor is still not interested in meeting our specifications, we can do one of several things. We can use certain parts of his assembly and replace the most objectionable parts with items of our own design and manufacture. We can evaluate the risk involved and decide how susceptible to failure the material is. Or we can pressure test the equipment and if necessary derate it.

We took this approach with the thermocouple vacuum gage tube needed to measure the pressure in vacuum systems. A Varian NRC 531 vacuum gage tube^{*} was selected. Its main body was made of extruded stainless steel 304. The header assembly consisted of: base - stainless steel 304, pins - alloy 52 (50% nickel; 49% iron; 1% silicon, magnesium, carbon), insulator - glass, filament wires - platinel, key - mild steel. The two parts were fastened together with a braze joint.

* Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research & Development Administration to the exclusion of others that may be suitable.

We asked the vendor to modify the gage to our specifications, but the vendor refused because the modifications were too expensive for the quantities we required. We therefore machined the main body at LLL, using our certified stainless steel 316, and used the header assembly as-is. We felt we could use the header assembly for several reasons. Although the commercial stainless steel 304 used in the base is not as reliable as our certified stainless steel 316, it is still compatible with tritium, and we decided the risk of failure was not worth the cost of change. The pins and the insulator are in compression in the header assembly and therefore their risk of failure is very low. Failure of the filament wires would not release tritium, and the key is not exposed to tritium at all. The braze joint was developed as a type 33 electron-beam weld.²

We made six assemblies and tested them as specified in Ref. 3. The testing showed that the new assembly was satisfactory; we also devised a pressure and acceptance test that can detect materials and fabrication failures that could not be detected by other methods. The test follows the following procedure:

1. Each gage is measured prior to and after pressurizing to 1.03×10^4 kPa (1500 psig). If it deforms more than 0.05 mm it is rejected.
2. Each gage is helium leak-checked during the test. If it has a leak detectable by a mass spectrometer capable of reading a leak rate of 1×10^{-9} atm cm³/s, it is rejected.

If the gage survives the test it is given an MAWP rating of 2060 kPa (300 psi), which is a safety factor of 5 on the test pressure.

These gages are now certified-stores stock and are immediately available. If there were no certified-stores stock, it would take about two years to obtain materials and components for each gage, assemble it, and inspect and certify it.

MANUFACTURING AND ASSEMBLY PROCESS SELECTION

Manufacturing and assembly processes must be specified because they affect the metallurgical properties of the material and the design of the system. We found that many vendors did not want to be bothered with changing their processes. The small size of our orders, the complications of complying with our quality assurance requirements, the involvement of a subcontractor,

and the process change itself made filling our orders very unattractive. Manufacturing and assembling in-house also presented problems, especially in the length and complication of the quality control procedure.

Creation of the certified-material storeroom solved several of the vendor-related problems. Because larger quantities can be ordered at once, it is economically more feasible for a vendor to change his processes and comply with our quality assurance requirements. When the vendor still will not provide the component we need, we then weigh the risk to the system against the effort required to develop an in-house process.

Weld joints are an example of a process developed in-house. The High Pressure Gas System had more than 500 critical weld joints, which could be grouped into about two dozen categories on the basis of the wall, configuration, and mass of the mating components. The weld preparation, weld procedure, and testing inspection had to be defined, and then a welder had to be certified to do the welds. His certification consisted of doing one practice weld and three test welds that are radiographed, checked with fluorescent penetrant, and examined metallurgically to verify that the welding technique is correct and repeatable. For a more detailed description of the weld requirements, see Ref. 2.

INSPECTION OF MATERIALS AND PROCESSES

Materials and processes must be inspected to ensure that they meet specifications. For vendor-supplied items we use the following methods:

1. Evaluation and inspection by LLL personnel at the vendor
2. Vendor documentation, such as certifications of the chemistry and physical properties of the material
3. Radiographic and other tests at LLL.

For items made and assembled at LLL, we use extensive inspection techniques such as pressure testing and radiography. Every step of the inspection process is carefully documented in accordance with Refs. 4 and 5. This includes using design drawings as check-off lists rather than developing separate lists. This procedure minimizes paperwork and time while providing complete documentation for each certified item. The procedure is detailed in Ref. 4.

JOINT DESIGN

A basic decision in joint design for tritium-handling systems was whether welded joints or mechanical joints should be used. Welded joints have the advantages that they do not have to be leak-checked prior to each run, they are not as susceptible to leaks due to tampering or accidental loosening, and they are not as susceptible to leaks due to temperature or vibration cycling. On the other hand, they are more expensive to make and test in the initial installation. Moreover, a system with welded joints is more difficult to modify or replace components. This is not completely unfavorable, however, as the additional effort to replace a component does help ensure that sufficient attention is given to the proper material, methods, testing, and documentation.

It was decided to use welded joints as much as possible, to increase reliability and to save operator time by eliminating leak checking prior to each run. A welded joint already existed for high-pressure components.⁶ It consisted of threading a high-pressure, thick-walled tube into a mating component such as a valve or fitting and then making a seal type weld. For low pressure components — pressures less than 11 376 kPa (1650 psig) — the basic type of joint was a socket weld.²

To ensure that good welded joints are made, the welds must be made by certified welders, all joints must be tested by liquid penetrant after they have been subjected to a pressure test at 150% MAWP, and as many joints as possible must be radiographed. In the High Pressure Gas System, only 17 welds out of more than 500 could not be radiographed because of their position and configuration.

For cases where welded joints are impossible or impractical, we chose two types of mechanical joints, one for high-pressure components and one for low-pressure components. For high-pressure components, Autoclave Engineering, Inc.'s HighPressure 60°-cone, threaded-tubing, metal-to-metal seal was used. This joint consists of a female part with a 60° cone, a threaded tube with a 59° cone end to fit into the 60° cone, a collar that threads onto the tube to provide an adjustable flange, and a gland nut that fits behind the collar. As the gland nut is screwed into the female housing, the assembly is seated.

For low-pressure components, the Cajon VCR vacuum coupling was used. It is a metal-to-metal seal using a disposable metal gasket. A disadvantage of the seal is that every time the joint is disassembled, the gasket must be replaced. If an unapproved material like nickel were used, this could lead to a failure. To emphasize the need for control of this part, a special "Cajon gasket log sheet" was made listing every Cajon certified joint. This listing is cross referenced on the schematic drawing and the fabrication drawings. If a joint is disconnected, the technician doing the work must list on the log sheet the purchase order number of the replacement gasket, the date installed, and his name and initials. The certified gaskets have red edges to distinguish them from uncertified gaskets.

SECONDARY CONTAINMENT

It is not possible to design, fabricate, and assemble all items to certification standards. Stainless steel 316 is not appropriate for some applications; in other cases, a necessary manufactured item that meets our specifications may be impossible to obtain. In these cases, we use secondary containment.

When we use secondary containment, we must answer the following questions:

1. Is the component material sufficiently compatible with tritium that it has a reasonable expected life? This is not a tritium release problem but an operational problem.
2. In the event of failure will the secondary container contain the tritium until it can be removed?
3. How will the secondary container be monitored for failure of the main component?
4. How will the tritium be removed from the secondary container?

An example of secondary containment in the High Pressure Gas System is the compressor enclosure.⁷ The Pressure Products, Incorporated diaphragm compressor was too difficult to certify as it had too many parts and manufacturing processes, and some of the parts would not function properly when made of stainless steel 316.

The first step for secondary containment was to modify some of the parts to make them compatible with tritium. The next step was to ensure that in the event of failure the secondary container would contain the tritium until the

tritium could be removed. The pressure of the secondary container if the 125 g were released to it was the critical factor. It was decided that during operation the atmosphere in the secondary container would be a vacuum. A test of the compressor showed that the minimum pressure at which it would operate was 27.5 kPa (4 psia) pressure, so during operation the secondary container has an argon atmosphere at 27.5 kPa. In the event of a failure in which all 125 g of tritium were released into the compressor enclosure, the final pressure would be 82.7 kPa (12 psia) which is still a partial vacuum. The enclosure pressure is monitored directly by a pressure transducer.

If tritium is released into the secondary container, it must then be removed. This can be done by several methods, including (1) using a uranium trap to recover the tritium or (2) using a Sprengel pump to pump the tritium into recovery tanks.

OPERATING PROCEDURES

Tighter control of actual operating procedures is the responsibility of the operating staff and will not be discussed in detail in this report. However, there are several mechanical devices in the High Pressure Gas System that are designed to counteract a mistake in operating procedure. Most are rupture disks in the low pressure systems. If by accident the wrong valve is opened and the high pressure gas enters the low pressure system, the rupture disk will burst and the gas will flow to a containment system designed to contain 125 g of tritium at about 482 kPa (70 psia). For systems where rupture disks are not practical, two valves in series are used. A failure thus requires either a double seat failure or double accidental valve openings.

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APPENDIX

CERTIFIED-MATERIAL STOREROOM

The certified-material storeroom was set up to handle stock for all tritium-handling systems. To minimize inventory costs, the number of stock items is kept as low as possible while permitting systems to be built or maintained. About 75% of a tritium-handling system can be built from certified stores stock.

For convenience, stock items are categorized by whether they are basic to high pressure — 0 to 1.4×10^5 kPa (0 to 20 000 psia) — systems, basic to low pressure — 0 to 11 346 kPa (0 to 1650 psia) — systems, or supplementary to both.

Basic High Pressure Components

The basic components of the High Pressure Gas System are:

1. Valves — We use Autoclave Engineers, Inc. 1/4-in. valves. Auxiliary Systems Group and Autoclave Engineers had jointly developed a seal welded joint for use with the valves, a quality assurance program for the commercial stainless steel 316 valves, and a stock list of the types of valves most commonly used. This experience was used in developing the certified stores requirements.
2. Tubing — Auxiliary Systems Group had previously established a stock of high pressure tubing using commercial stainless steel 316. The size selected for standardization was 1/4-in. o.d. $\times$ 0.084-in. wall. Auxiliary Systems Group experience was extended to provide certified tubing made from our certified stainless steel 316.
3. Fittings — Autoclave Engineers, Inc. fittings were used to match the 1/4-in. high pressure tubing.

All these components are rated at 2.07×10^5 kPa (30 000 psia) or greater except for their weld joints. To maintain a safety factor of 4, the weld joints can be rated only at 1.4×10^5 kPa (20 000 psia). However, because of our rigid quality assurance program, we have been able to rate the weld joints at 1.7×10^5 kPa (25 000 psia) — a safety factor of 3.27.¹

Basic Low Pressure Components

The low pressure gas system has the following basic components:

1. Valves — Nupro Products Company bellows-sealed 3/8-in. valves were selected. The valves in stock have all their wetted parts made from LLL stainless steel 316 except the bellows, which is commercial stainless steel 347. Because of the possibility of a failure in the bellows, a "U" series valve is used where tritium will normally flow through the valve. The "U" series valve has a Teflon-sealed bonnet that provides secondary containment if the bellows should fail. The bonnet also has two ports that can be used for evacuation, leak testing, and monitoring the bonnet area. The uncertified parts in the bonnet area would have to be replaced if tritium got into this area. Less-expensive "T" series valves are used in the systems that will handle tritium only if some component has failed. The "T" is the same as the "U" except it is not sealed in the bonnet area. Both valves have a maximum LLL pressure rating of 1.13×10^4 kPa (1650 psi), a pressure that permits a 150% pressure test without affecting the bellows.
2. Tubing — Two sizes were selected: 3/8-in. o.d. $\times$ 0.035-in. wall and 1/4-in. o.d. $\times$ 0.020-in. wall. The 1/4-in. size was selected for transition requirements to the 1/4-in. o.d. nominal high pressure tubing systems. The tubing is rated at 2.07×10^4 kPa (3000 psi).
3. Fittings — Cajon Company socket weld fittings to match the tubing sizes were selected. The fittings have a rating greater than 3.4×10^4 kPa (5000 psi).
4. Couplings — Cajon Company VCR couplings (described in the section on joint design) were used. The couplings have a rating greater than 3.4×10^4 kPa (5000 psi).

Supplementary Items

Supplementary items include:

1. Bar stock and billets for making components.
2. Rupture disks, pressure rated at 30, 45, 65, 150, 200, 800, and 6000 psig. (207, 310, 448, 1034, 1379, 5515, and 41 400 kPa).²
3. Containment tanks (40 litre), for use as emergency tanks.³ They contain tritium only if some component fails.

4. Recovery tanks (40 litre), for use in systems that normally contain tritium.⁴
5. Weld wire
6. Butt weld sleeves
7. Thermocouple vacuum gage tubes, a commercial item modified to a certified item that in an emergency could withstand 2068 kPa (300 psi) tritium⁵ (described in the section on materials selection).

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