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ABSTRACT

In the past JET has suffered from a number of vacuum leaks on components such as bellows, windows and feedthroughs due, in part, to the adverse conditions, including high mechanical forces, which may prevail during plasma operation. Therefore before the recent Tritium experiments on JET it was deemed prudent to manufacture and install items with a secondary containment or interspace in order to minimise the effect of failure of the primary vacuum barrier on both the leak integrity of the machine and the outcome of the experiments.

This paper describes the philosophy, logistics, method and implementation of an integrated connection and monitoring system on the 330 interspaces currently in position on the JET machine. Using the JET leak database comparisons are drawn of leak failure rates of the components allied to the number of operational hours, prior to the system being present and after installation and commissioning, and the ease of detection compared to the previous situation. An argument is also presented on the feasibility and adaptability of this system to any large complex machine and the benefits to be obtained in reduction of leaks and operational down time.

INTRODUCTION

JET is the largest nuclear fusion experimental facility in the world and has recently completed an operational campaign (DTE1) where, by utilising the Hydrogen isotopes of Deuterium and Tritium, and creating and heating the magnetically confined plasma to extremely high temperatures, world record amounts of fusion energy were produced. As this involved the routine handling of Tritium, which is radioactive, all previous component leak failures [1] by air ingress into the machine during operations were analysed and those items which were perceived to have a greater risk were replaced by components having a double containment. This meant in practice that all windows, a majority of the bellows, and current and instrumentation feedthroughs [2] with an interspace between the primary vacuum boundary and outside atmosphere were manufactured, and installed in the preceding machine shutdowns to DTE1. The numbers of individual interspaces upon which the design was based were 114 windows, 124 bellows, 30 internal volumes, 45 feedthroughs, 11 miscellaneous diagnostics and 4 beryllium evaporators. This resulted in some 330 interspaces being present on the JET machine and how these were dealt with and the resulting effect on machine reliability is the subject of this paper.

POLICY AND LOGISTICS

JET is a very complex machine with a highly regulated system of working, which ensures that all interfaces and possible conflicts are resolved, before any pieces of equipment are installed on the Torus. Therefore to produce an integrated system of interspace connections a series of discussions took place where the following policy decisions were adopted.

1. All equipment interspaces currently being designed and manufactured were to have the same connection but those that were already existing would be fitted with adapters to bring them into line. The connection chosen was of the compression type with the trademark ‘ Swagelok’ with an outside tube diameter of _” as these had been shown by rigorous tests to be resistant to damage and could be repeatedly sealed without showing degradation in seal and vacuum integrity.
2. JET is divided into 8 Octants so all of the interspaces on one octant were taken as a group with additional sub-divisions on the upper, mid-plane, and lower part of the machine. A responsible officer was appointed for each octant to establish the number and position of each interspace on that octant and to produce a schematic showing all the inter-connections, an example of which is shown in Figure 1, and to act as a liaison person for the individual interspace responsible officers. A central co-ordinator was appointed with overall responsibility for the design, procurement, installation and commissioning of the system.

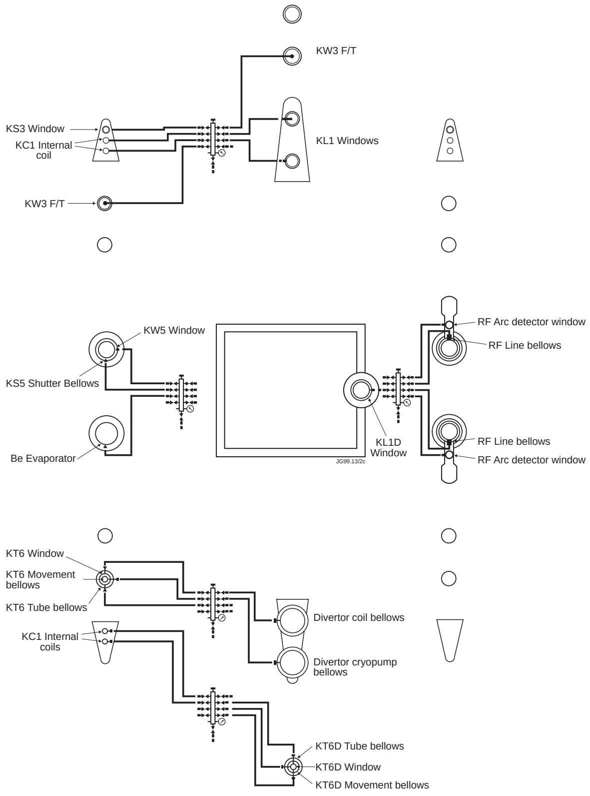

Fig.1: Schematic of Octant 1 Interspaces

3. A standardised manifold design, based on grouping together a maximum of 9 interspaces in the same vicinity, was established incorporating an outlet valve, a facility for up to 9 inlet valves to individual interspaces, an over-pressure protection and a simple Bourdon type gauge. Enough flexibility was to be built into the manifold design to accommodate additional interspaces should any be added by installation of new equipment at a later date. All the interconnections to be done were of the above mentioned ‘Swagelok’ type. The manifolds were mounted on each octant in the same position so pipe runs could be standardised. Since each Octant comprises 5 rigid and 4 bellows sectors to increase the toroidal electrical resistance of the Torus, all pipe runs crossing a bellows section had to have an electrical break to prevent high currents being induced in small bore piping during plasma fault conditions. This was accomplished using double walled butyl rubber tubing.
4. Interspaces, with one exception where for thermal conductivity considerations it was to remain under vacuum, were to be filled with 500 mbar Neon to act as a tracer gas in the event of failure of the primary . Neon was chosen because it had no problems with neutron

bombardment induced long life isotopes, it is an inert gas so the effect on machine conditioning would be minimal, it has a specific footprint mass spectra with a 10% isotopic peak on mass 22 which could be easily detected even in the presence of carbon- deuterium compounds which abound in JET due to plasma operation. The filling pressure of 500 mbar when cold was selected because it would not go over atmospheric pressure when the Torus was baked. Also if the pressure on the manifold gauge was observed to decrease below 500 mbar it would indicate a primary barrier leak, and if it went up beyond an arbitrary limit of 800 mbar accounting for thermal pressure increases it would indicate a secondary barrier leak and in the case of windows it would reduce the differential pressure on both primary and secondary interfaces to $\frac{1}{2}$ bar.

Having established the policy a list of interspaces was compiled using a standard database and manufacturing drawings were produced showing a schematic of each octant and approximate routing for the pipes ready for the work to commence to build the system.

INSTALLATION AND COMMISSIONING.

As a first stage in the installation process all manifolds were assembled after first establishing the number of inlet valves for a specific position. A photograph of a typical manifold is shown in Figure 2. The valves are of a standard bellows sealed toggle design with a 'Vespel' seat for reliability and ease of use. They were then mounted on the JET machine using special brackets and insulation bushes and plates to electrically isolate them from the JET vacuum vessel. The mounting points were chosen to keep the pipe runs to the minimum length possible and were all on the central C sector of the machine, utilising existing fixing points on the upper and lower main vertical ports and the main horizontal port.

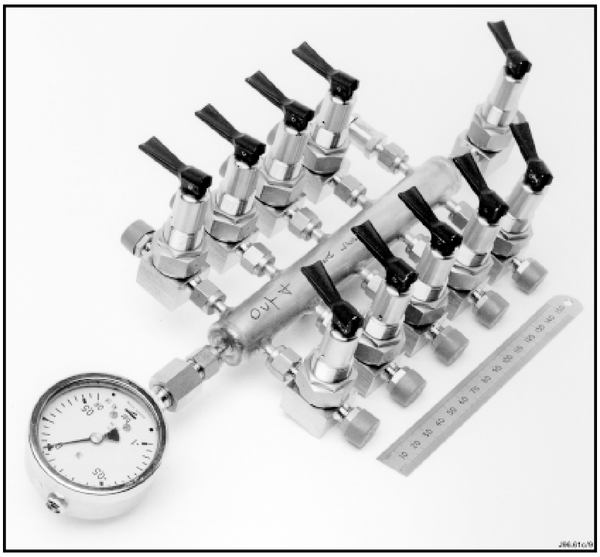

Fig.2: Photograph of a Typical Manifold

After checking that all interspace connections were of the standard set or had been adapted to be so the pipe runs were installed and after completion of a particular manifold, all connections tightened. To distinguish the pipes from the surrounding environment and make identification easier all rigid pipe sections were covered in blue shrink wrap. (The butyl rubber tube was purchased to match this.) An example of an installation on a typical main horizontal and main vertical port is shown in the photographs Figures 3 and 4 respectively. This illustrates the complexity of the task extremely well.

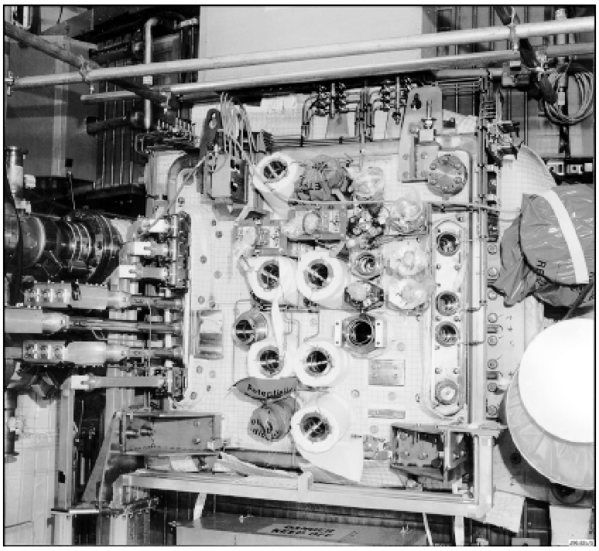

Fig.3: Photograph of a JET Main Horizontal Port Assembly

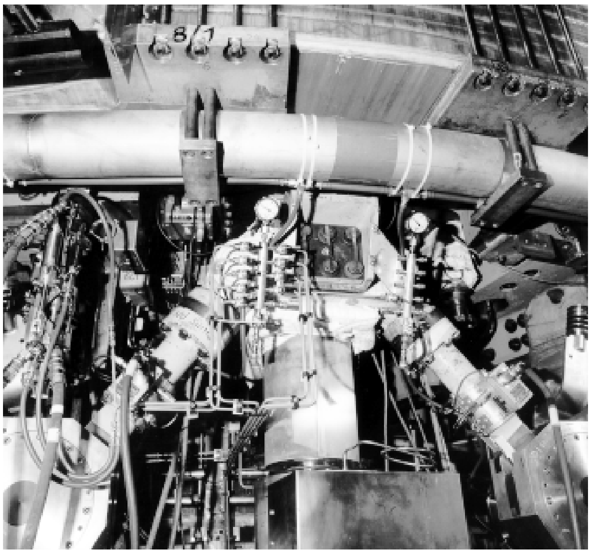

Fig.4: Photograph of a JET Main Vertical Port Assembly

The commissioning consisted of leak detecting all manifolds as they were completed using a commercial helium mass spectrometer leak detector to a leak rate specification of better than 1.0×10^{-9} mbar . l/sec. then back-filling the manifold assembly including all attached interspaces to a pressure of 500 mbar Neon followed by closing and locking the manifold outlet vale to prevent accidental venting.

EXPERIENCES.

Since the interspace system has been installed and commissioned, during the 1996 shutdown there has been 25 leaks in total which occurred during JET operations consisting of 7 window, 3 valve seat, 3 seal, 5 bellows,3 welds, 3 feed-through, and 1 gauge vacuum leak. Of these 14 have been installed with interspaces and so have been located by observing the pressure decrease in the particular manifold connected to that interspace. So by pumping out the manifold and opening each inlet valve in turn until a corresponding decrease has been seen in the level of neon in the Torus as measured by the Torus RGA, the leaking item may be located . All that is left to do then is close that particular inlet valve and refill the manifold with neon together with the remainder of the interspaces on that manifold. This takes in time about _ hour as compared with an average of 6 hours to locate a leak in the past so saving the project around 77 hours in leak detection time and eliminating the leak, without recourse to cooling, venting and repair followed by pump-down and vessel conditioning taking in total per leak, an additional 2 -3 weeks [3]. The remainder of the leaks listed were, with one exception, less that the tolerated level of 5×10^{-5} mbar. l/sec. and so could be ignored.

Figure 5 shows a bar graph of leaks per 100 hours operation for various categories since JET commenced operation in 1983 and this illustrates the point that, although interspace leaks have increased in the last 2 years no effect was had on machine operations. Regular checks on the pressures in the 40 manifolds present on the JET machine have been done to spot any emerging problems. A continuos trace of Mass 20 in the Torus is maintained not only to spot any developing interspace leak but also to trace the time of any large leaks where the neon is pumped away in less than 5 minutes.

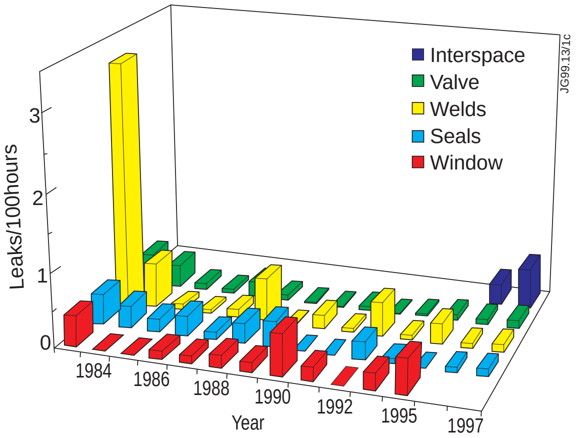

Fig.5: Bar Graph of JET Operational leaks by Categories

CONCLUSIONS

It has been demonstrated at JET that by the use of an integrated interspace system on those items which are prone to leaks, machine down time has been greatly reduced and the onerous task of leak location and repair has been greatly eased.

This system could be applied with some modifications to any large complex vacuum installation and will be of even great benefit in the large fusion machines now under consideration.

ACKNOWLEDGEMENTS

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