International Maintenance Review Board Policy Board (IMRBPB)
Issue Paper (IP)

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Title: Handling of pressure cylinders within MSG-3

Submitter: Boeing

Applies To:	
Vol 1:	X
Vol 2:	X
IMPS:	

Issue:

The TCHs requirements for maintenance task of pressurized cylinders installed on aircraft vary for the same part number posing a problem for airline operators. Some TCHs have no requirement in their MRBR / MPD and others have a requirement. Operators are particularly affected when they have multiple models of aircraft manufactured by different TCHs.

Problem:

Some TCHs require airlines to use their discretion and adopt national requirements for pressurized cylinders in their maintenance programs. Other TCHs have included it as an ICA in the MRBR. Irrespective of whether the requirement is classified as an ICA or not, presently the hydrostatic test is used as the method to address the risk of the pressurized bottles rupturing while installed on the aircraft. Going forward, when the industry performs MSG-3 analysis of the pressurized cylinders, MPIG members are unsure whether the hydrostatic test is an applicable and effective task to reduce the probability of failure. Therefore, MPIG requested feedback from its members regarding the hydrostatic test and these comments are below.

Airbus:

Airbus has never taken credit for DOT requirements as we do not assume that all worldwide operators are required to observe them. Thus if we wish to include the hydrostatic test as an aircraft level ICA we are obliged to publish the requirement in an ICA document. If we do not do this then operators will understand that the continued airworthiness of the aircraft would not be impacted if they chose not to perform regular hydrostatic tests of pressure cylinders. There are only two options for promulgating scheduled maintenance tasks as ICAs – the MRB Report or Airworthiness Limitation Section. The ALS would be the appropriate location if the task is identified as necessary to support the 25.1309 compliance demonstration. While pressure cylinder failures are included in multiple Failure Conditions within ATA 26 and 35 SSAs, none of the analyses has identified the need for the hydrostatic test. Hence, today, Airbus does not consider the hydrostatic test as a Candidate CMR, nor is the bottle identified as having a mandatory Life Limit.

Airbus has concluded that if it is necessary to identify the hydrostatic test as an ICA it is necessary to include it in the MRB Report. The method of addressing the bottles in the MSG-3 logic has always caused discussion within both the company (between analysts and between analysts and the design office) and with operators in MWG environment. It has not been easy to establish a common approach across all programs due to quite different views from different parties on two key points:

1) whether a sudden (explosive) rupture of the bottle should be considered as a realistic failure cause

And

2) whether a hydrostatic test is really an effective task to reduce the risk of any bottle failures identified in the MSG-3 analyses as failure causes

With respect to (1) Airbus acknowledges that the probability of a sudden rupture is very low. However, MSG-3 does not provide criteria to exclude the consideration of a failure cause on the basis of probability. If the failure is foreseeable then it needs to be considered. Sudden ruptures have occurred (the B747 O2 bottle incident in QFA being one that is often quoted). Airbus has not been able to conclude that the failure is unrealistic and therefore includes the sudden rupture as a failure cause. We however question whether other TCHs have been able to agree with their MRBs that certain types of pressure cylinder cannot suffer a sudden rupture. Should the sudden rupture only be considered as realistic on metallic rather than composite bottles?

A sudden rupture will release the full bottle contents immediately. Debris from the bottle may cause local damage to systems and structure. While system installation design rules ensure that the risk of multiple system failures is minimised, penetration of the fuselage structure may lead to decompression and the potential need for emergency action. The significance of O2 bottle failures will generally be greater than firex bottle failures due to the potential to release oxygen in an environment that might include sparking wires resulting from damage by bottle debris in addition to the loss of oxygen that might be needed during any emergency descent. Since both ATA26 and ATA35 bottles are supporting safety functions they are classed as safety equipment and thus MSG-3 FEC 5 or 8 logic must be followed, both of which require a task to be selected. Airbus considers that the consequences of a sudden rupture of an O2 bottle justify FEC 5 logic even if the probability of loss of aircraft for this reason has been minimised by close attention to the local installation. Note that this philosophy is not reflected in all our MRB Reports.

With respect to (2) Airbus has typically identified the hydrostatic test (HST) as an effective task to minimise the risk of sudden rupture. It has been questioned whether a detailed inspection (DET) of the bottle would be sufficient to satisfy MSG-3 logic. This however cannot assess any deterioration that might occur inside the bottle and, if the bottle construction includes a screwed cap/head, some dismantling would be required to visually inspect the condition of the threads (which would typically be done at the opportunity of the HST). To date, Airbus has not used a DET to satisfy the FEC8 logic.

Similarly, Airbus has not concluded that a discard task is the most effective means to address the logic. This would require the bottle to be discarded irrespective of its condition at an age defined by the MWG (which would probably be obliged to take the vendor recommendation in the absence of data to justify a longer period). Vendor recommended life limits typically include reference to the number of times they have been subjected to HST for which the vendor also makes a recommendation. It thus becomes problematic to identify a value if the vendor's HST recommendation is not also included as an ICA. Airbus has not seen the need to introduce both the HST and discard as effective tasks to satisfy the MSG-3 logic.

However, Airbus has recently been challenged by the EASA MRB on the effectiveness of the HST as a task to reduce the probability of bottle failure. They cite the fact that in the B747 case the bottle had successfully passed an HST only a few months earlier. Airbus acknowledges that there have been very few bottle failures during HST accomplishment. However, some bottles are scrapped at this opportunity following visual inspection of their condition. Those exhibiting degradation are not subjected to HST and thus it is not possible to declare that those bottles would have passed the HST had it been conducted. Thus, while we have no evidence that HST is an effective way to reduce the risk of failure, we question whether the good in-service reliability of the bottles may well be the result of detailed inspections being performed at the opportunity of the HST. Bottle vendors continue to recommend HST and thus many operators will continue to schedule these irrespective of whether they are MRBR tasks. Presumably these vendors believe the HST is effective but are they requiring it more for historical or commercial reasons than as a means to reduce the potential for failure in service? There have been significant improvements in design over the decades but the vendor's HST recommendations do not seem to change.

In conclusion, Airbus supports an Industry initiative to provide guidance in MSG-3 to drive common set of tasks for bottles having the same type of construction. The effect of failure (sudden rupture) is likely to be very similar on all aircraft types and operators expect that the ICA requirements for bottles of the same part number should be identical, irrespective of the type it is fitted on. The current mix of no task, HST, DET and DIS is probably not justified and is causing difficulties to operators.

Our current position is that MSG-3 should perhaps clarify that sudden rupture should be considered as a realistic failure mode and that an HST is an effective task to minimise the risk of failure (even if it is the dismantling and visual inspection at the opportunity of the HST that brings the most benefit). We are however very open to discussion on this and look forward to reviewing the positions of the other TCHs.

American Airlines (AAL):

At AA, there is no requirement to record the number of hydrostatic tests accomplished or which ones fail. It's still a paper form that has a minimal amount of information that we are required to keep for the FAA to review.

All Nippon Airways (ANA):

ANA provided data from hydrostatic tests and visual inspections from their shop. Based on their data, ANA believes that hydrostatic test is not an applicable and effective task for MSG-3 analysis.

Boeing:

Over the years, Boeing has not performed MSG-3 analysis of pressurized containers and therefore does not have a requirement for any of its models in the MRBR document. However, in some models, it listed in the MPD as a DOT requirement. To harmonize requirements across the fleets and reduce maintenance burden for operators outside the US, the hydrostatic test was removed and left to the operators to include it in their maintenance program based on their national requirements. Boeing's opinion is that if the pressurized containers are to be considered as part of the MSG-3 analysis, then the hydrostatic test is not an applicable and effective task. Boeing believes the industry as a whole needs to understand the failure modes and causes of pressurized containers and its effect to determine a new preventive maintenance task that will be applicable and effective to reduce the probability of failure.

Bombardier:

Bombardier does consider rupture (failure) of the pressure vessel as a realistic failure mode in our MSG-3 analyses. A Restoration task meeting the intent of Hydrostatic testing has been selected as an applicable and effective means for validating the structural integrity/condition of the cylinder/bottle for continued use in service. The interval is based on National Regulations and the Cylinder Manufacturer recommendations.

British Airways (BAW):

Over a number of years British Airways has had its own workshops fully approved to manage pressurised bottles. We have tested and inspected a vast number of bottles in this period and have the following to offer.

From a system analysis, (bottle contents, (Medium)), perspective there are fundamentally two approaches that need to be taken.

On a vessel that is either charged or discharged, (such as an inflation source bottle – slide raft, door assist – or a fire bottle), the hoop and axial stresses do not change in service. When the bottle discharges the stress reduction is almost instantaneous. Any internal corrosion will increase the stress levels in the area where corrosion is evident, and the corrosion will act as a stress raiser, exacerbating the effect over time. This corrosion can be caused by various mechanisms, ranging from straight forward oxidation to stress corrosion itself. This can be minimised by charging with nitrogen so there is no oxygen to cause oxidation such that it only leaves stress corrosion as a concern.

A vessel that isn't corroded or degrading in service by the act of corrosion and which remains fully charged is never going to rupture spontaneously unless it is otherwise damaged. There is no change to the stress applied and thus no fatigue will be evident.

By hydrostatically testing the bottle, you are deliberately pumping it up to pressures beyond its operating range to see if it ruptures or experiences plastic deformation. The former of which speaks for itself but the latter, by its very nature is introducing excessive loads into the vessel. If the bottle plastically deforms then it becomes scrapped, if it doesn't there has still been an unnecessary stress cycle applied to the bottle, which could be enough to materially weaken it in some way, hence there is no way of determining the new factor of safety. Arguably the act of testing the bottle increases the risk of in service rupture owing to the stress cycle applied during the test.

In the case where MRBR's have historically drawn upon DoT requirements BA have utilised the provisions in CFR 49, Part 180.205 paragraph C), to justify bottles remaining in service beyond published ICA requiring HST, the CFR states:

"A cylinder may be re-qualified at any time during or before the month and year that requalification is due. However <u>a cylinder filled before the requalification becomes due may remain in service until it is emptied.</u> A cylinder with a specified service life may not be refilled and offered for transportation after its authorised service life has expired".

This would suggest that the HST isn't that critical, and that vessels fitted to aircraft are, effectively, fit and forget until they are discharged!

Turning the attention to the more critical area of oxygen bottles which we believe should be considered in detail as part of the aircraft system for analysis and requirements purposes.

By their very nature oxygen cylinders are discharged and replenished throughout their operating life. The very act of using them varies the hoop and axial stresses.

If you add into this environment that aviation oxygen is not completely pure, (albeit that it impossible to get it any purer), and contains an amount of water vapour. As long as the oxygen pressure remains above about 450psi, the water vapour stays as a vapour and does not condense onto the internal surfaces of the bottle. However, below that pressure it does. Having liquid-form water in an oxygen rich environment in not desirable when it comes to corrosion prevention so the approach to pressure testing, (if required), is quite critical and should be taken into consideration as part pf the analysis or ICA of the bottle.

BA do not utilise the justification statement in CFR 49 eluded to above, in the case of oxygen bottles. The DoT requirements for HST and radiographic inspection, (if specified), are adhered to strictly.

Oxygen bottles by design are 3000 psi capable, but are only ever charged to 1750 psi. Because the bottles are 3000 psi capable, (which means they are actually capable of 5000 psi by design taking into account the factors of safety), the act of performing a 3000 psi HST is not much of a risk in over stressing the bottle.

BA approach oxygen bottle testing quite rigidly, though. The BA Standard minimum pressure acceptable for replenishment is 750 psi. If the bottle is depleted below that pressure it is overhauled before replenishment, irrespective of the date that it was last tested/overhauled.

Considering all of the above, it is the view of BA that having a hard time, calendar based HST in any ICA is fundamentally flawed and does not provide the level of safety that it is trying to achieve. It is a far better approach to treat bottles that are either fully charged or not differently to oxygen bottles.

We would like the MSG-3 approach to system analysis and the TCH issuing ICA to adopt the following:

Bottles such as inflation source bottles that are either charged or not, have NO hard calendar based HST requirements and are treated as per CFR 49 180.205, (only require a test post discharged for the first time with an ultimate scrap life possibly applied where necessary.

Oxygen bottles are overhauled after each depletion to 450 psi or below irrespective of the last overhaul date or nominal next due date, (Our BA standard of 750 psi give us some additional leeway but is not required in industry).

Off wing and On wing DVIs of ALL pressure vessels for internal and external damage, (as appropriate), and age related damage should be carried out.

Gulfstream:

Bottle failures due to the structural failure were considered to the extent of leakage. Although not explicit in the MSG-3 dossier, a bottle burst was not considered as a realistic failure mode. Considerations for the effects of a burst pressure vessel were assessed in the Aircraft Zonal Safety Analysis as part of the Particular Risks Analyses. In Gulfstream's examples, all tasks were selected as 'degradation detection tasks', not as 'failure finding tasks'.

Example from MSI 35-XX**:** Considered the following:

Function 1 - To provide oxygen storage.

F. Failure A - Fails to provide oxygen storage.

F. Effect 1 - No effect as a single failure, reduction in total quantity of oxygen available. If required, a second oxygen bottle is available to provide oxygen for the crew and passengers. Failure Cause b - Crew / Passenger Oxygen Cylinder/Regulator Assembly (Bottle fails/fractures: loss of oxygen)

Level 2 analysis identified 2 tasks as applicable and effective:

RST for Hydrostatic test

DIS of the bottle @ XX years from date of manufacture

Note from the failure effect that it was considered that the failure would not cause a burst (explosion). The effect is commensurate with oxygen leakage, which is the Function under analysis. There is another function for the system overpressure, but is not related to the bottle fracture.

Examples from MSIs 26-21 and 26-24:

We had a similar approach to the Engine and APU Firex Bottles and Portable firex bottles, which addresses leakage:

Level 2 analysis identified one task as applicable and effective:

RST for Hydrostatic test

Although they are all pressure cylinders, the Oxygen bottles are expected to be serviced much more often than the Engine and APU firex bottles, for example. This was taken into account when establishing or not an MRBR for the DIS. It is expected that the firex bottles are less susceptible to fatigue as they are not emptied as often. Installation areas were also taken into account for Delta P qualitative effects. Service history was used to justify (or substantiate) the MRBR task interval, as well as operators feedback.

Mitsubishi Aircraft:

As you know, MRJ MRBR is under development, and we discussed in the past WG if hydrostatic tests on high pressure bottles should be selected in MRBR.

As a conclusion, Mitsubishi did not select the hydrostatic tests of the fire extinguisher bottles in MRJ MRBR based on the WG discussion because

- they are not considered technically required because of very few findings at hydrostatic tests.
- they are linked with national policy or regulation of each country.
- an MRBR contains the initial minimum scheduled maintenance/inspection requirements.
- tasks should not be established only to fulfill a known regulatory requirement.
- only tasks that fulfill the applicability and effectiveness criteria shall be selected.

In addition, please be informed that we do not consider a sudden rupture as a realistic and valid failure mode.

Republic Airways:

Our bottles were part of a pool program when they came due and we rarely got the same bottle back. So we do not know if bottles failed the test since all we got back were good bottles that are not necessarily the same SN that we sent out. The hydrostatic test failure rate the vendor is seeing is understood to be 0.1%.

Textron Aviation:

Textron Aviation does not believe a Hydrostatic test is an effective or applicable scheduled maintenance task that will reduce the risk of an airplane pressurized cylinder failure on our products.

After much discussion, our various ISCs, including our FAA and EASA MRB Chairpersons have concluded the same. As a result, we do not have any pressure cylinder hydrostatic checks mentioned anywhere in our MRBRs.

We do, of course, analyze all aircraft systems that use pressurized cylinders and typically select a Standalone GVI task for all pressurized cylinders.

For Fire bottles, (ours have a low pressure switch threaded directly into the bottle) we typically end up selecting a Category 9 Fire Bottle Low Pressure Switch Function Check. Most of our fire bottle vendors recommend doing the pressure switch check during the Hydrostatic test, not to exceed 60 Months. So, because we don't have a scheduled hydrostatic test requirement, our customers either buy an exchange fire bottle every 60 months or check the switch themselves using the suppliers CMM ICA.

UPS:

About 6-7 years ago Qantas had an O2 bottle rupture in flight on a 747-400 near Philippines – quite dramatic photos of the hole in the side of the fuselage and such. UPS believes the Australian Accident Investigation Board had quite a lot of information on bottle reliability.

http://avherald.com/h?article=40a29b54/0045&opt=2304

The data available at UPS is limited to what their own hydrostatic shop performs, which is the large Scott/Zodiac (115 cu ft) oxygen bottles P/N 801307-00 classified as DOT-3HT-1850 reservoir.

In 2016, UPS tested 422 bottles and had one fail hydrostatic test. So far in 2017 UPS has tested 143 bottles and had one failure.

Recommendation (including Implementation):

Based on the comments received by MPIG members, it is not evident that the performance of a hydrostatic test has any correlation with the high level of safety of pressurized cylinders currently experienced during airline operations.

In the interests of establishing a common approach to the application of MSG-3 logic on different aircraft types and in consideration of the value in permitting carriers to maintain pressure cylinders according to a standard practice, it is proposed that, exceptionally, the MSG-3 document will prescribe certain criteria in order to achieve a more harmonised set of scheduled maintenance tasks.

The majority of MPIG manufacturer members have successfully demonstrated to their MRBs that a Hydrostatic Test is not an effective task to maintain the continued airworthiness of the cylinders. As a result, a statement will now be made in the MSG-3 document that a task other than a Hydrostatic Test should be identified to maintain an acceptable failure probability for pressurized cylinders.

Boeing has contacted Meggit and Walter Kidde, the major manufacturers of pressurized bottles to appraise them of MPIG's position regarding hydrostatic tests. At time of submittal of the CIP to the IMRBPB no feedback had been received from them regarding their position and recommendation.

MPIG proposes adding a second specified subject in paragraph 2-3-4 of Volume 1 and Volume 2 of the ATA MSG-3 Operator / Manufacturer Scheduled Maintenance Revision 2015.1 documents to address "Pressurized Cylinders".

2-3-4. Procedure

This procedure requires consideration of the functional failures, failure causes, and the applicability/effectiveness of each task. Each functional failure processed through the logic will be directed into one of five Failure Effect categories [Subject 2-3-6].

Fault Tolerant Systems

By definition, the implementation of …….

Pressurized Cylinders

Historical data has shown that the performance of a Hydrostatic Test has no correlation to the high level of safety of the pressurized cylinders and is deemed as not applicable and effective.

To drive a harmonised approach in the consideration of pressure cylinders, the MSG-3 analyst should observe the following:

a) A sudden rupture of a cylinder shall be identified as a failure cause and shall thus be included in the logic analysis. The effect of such a failure may be greater than the loss of the system in which the bottle is installed.

b) The Hydrostatic Test typically recommended by the cylinder vendor (and possibly also the subject of National Requirements) is not considered an effective task to satisfy MSG-3 logic. An appropriate inspection or discard task should be selected as an applicable and effective task.

The materials used in the cylinder construction may affect the severity of the consequences of a sudden rupture as well as influencing the failure probability and thus the recommended task interval.

In determining task type and interval, consideration shall be given to the use of the cylinder with particular attention being given to cylinders that are regularly refilled in service to address normal usage (e.g. oxygen), these being more likely to experience degradation caused through more frequent handling and being more susceptible to the introduction of moisture or other contaminants.

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Status of Issue Paper (when closed state the closure date):

Retroactive: No.

Important Note: The IMRBPB positions are not policy. Positions become policy only when the policy is issued formally by the appropriate National Aviation Authority.