GREAT NEW GREASE, BUT CAN I USE IT?

GUIDELINES FOR QUALIFICATION OF NEW FLUID LUBRICANTS

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ABSTRACT

Space mechanism engineers often rely on oils and greases selected from a limited set of very long-established products. Today's evolving technical and environmental demands are driving interest in alternatives, but concerns about heritage, risk, and insufficient product data may hinder both adoption and approval of new oils and greases for space use.

This paper presents updated, industry reviewed and now formally adopted guidelines, which define ESA's recommendations on the minimum verification and validation test data required to justify adoption of new fluid lubricants. The guidelines remove doubt concerning the pre-requisites for new lubricant implementation in mechanism qualification programmes overseen by ESA.

1 BACKGROUND

Formulated low volatility fluid lubricants (oil and grease products) used today in spacecraft mechanisms are predominantly based on oils from two chemical families: the PFPEs (perfluorinated polyethers, usually of Z-type within Europe), which have been in use since the 1970s [1]; and the synthetic hydrocarbons (commonly multiply alkylated cyclopentanes (MACs)), which originated in the early 1990s [2].

Products based on these chemistries, such as the oils Brayco 815Z, Fomblin Z25 and Nye 2001A, and their derived greases, including Braycote 601EF, MAPLUB PF100 and Rheolube 2000 have very extensive flight use, having been used in many qualified space mechanisms.

The selection of a lubricant from amongst these, and several other, long-established products brings confidence that their adoption in new applications will be relatively low risk due to their extensive prior use, a characteristic sometimes called "heritage".

Heritage products dominate the space market; but have well-known limitations [3]. In general, PFPEs can be used over a wider range of temperatures than MACs and have a lower volatility. However, PFPEs exhibit relatively low tribological lifetimes and generally poorer performance under boundary lubrication than MACs. It can be challenging to select a lubricant for missions requiring some combination of long tribological life, high temperature operation, low speed boundary regime running, and a critical need to avoid contamination.

Furthermore, the remarkable chemical stability offered by PFPEs, which is a significant benefit in space applications, unfortunately renders the oils, their related solvents and myriad other so-called "PFAS", or per- and polyfluoroalkyl substances as environmental contaminants on Earth. Emerging environmental legislation threatens to curtail, and perhaps even ultimately prohibit, the production and use of PFPEs. Currently [4], the restriction process within the EU, for example, remains with the ECHA scientific committees for evaluation and the initial restriction proposal by five Member States foresees a ban approach with a 12-year derogation expiring, in a worst case, c.a. 2041. Note this may have wider implications, demanding process changes, and/or restricting (or even prohibiting) production of other fluorinated polymers (e.g. PTFE) widely for space applications in cage materials, plain bushes, electrical wiring and greases as thickeners etc.

Though today the price, availability, and minimum order quantities of PFPE lubricants, and associated fluorinated solvents, remain acceptable. The producers of fluorinated materials are clearly concerned by the potential impact of proposed restrictions. Many lubricant manufacturers are already considering non-PTFE thickeners [5] and both the long-term robustness of the PFPE supply chain and the use of PTFE thickened lubricants for space is therefore unclear. Already some well-known fluorinated materials commonly used for space, e.g. the creep barrier 3M Novec 2708, and several fluorinated solvents are being withdrawn from the market.

Finally, the evolution of new products should be considered. New additives, thickener materials and processing routes are constantly being evolved, leading to newly formulated lubricant products, even when based on heritage base oils. Beyond this, new base oil chemistries, such as ionic liquids [6], whilst not yet widely employed, have attractive characteristics. These base fluids may soon be offered as fully formulated products with specific benefits for various space applications. These new products (by definition) lack heritage, meaning that their use in a space mechanism can bring perceived risks, which need to be retired for the new fluid selection to be accepted.

Against this background, ESTL was asked by ESA to generate a guideline document, “Guidelines for Qualification of New Fluid Lubricants” [7]. These guidelines clarify ESA’s position on the necessary process verification and product validation data, needed as pre-requisites for including a new lubricant (or modified formulation) in a mechanism qualification test campaign.

The document itself was highlighted in an ESMATS paper in 2023 [8] and released at Issue 1 in January 2024 for comment by industry. In parallel, during 2024, ESTL itself ran two lubricants, one well-known, the other very new, through an experimental programme using the guideline’s recommended processes as a “process stress test”.

The guideline document has now been updated and was formally released at Issue 2 taking into account the comments received from industry, from ESA and our own reflections on the process and lessons learned during assessment of the two lubricants which were evaluated. This up-issue, released in April 2025, has now been adopted by ESA reflecting its formal expectations concerning the introduction of new fluid lubricants into programmes which it oversees. Hence, in response to the question posed in the title of this paper “Great New Grease, But Can I Use It?” – the answer from ESA will likely be “No” – unless the process documented in the guideline and presented herein has been followed and the appropriate test data made available at the appropriate review stages.

The remainder of this paper presents an overview of the main elements of the now formalised document (which can be accessed at the Members’ Area of ESTL’s website) and highlights the changes implemented.

2 QUALIFICATION TERMINOLOGY

Within the space industry, the terms “qualification” or “qualified” are much used, although often incorrectly and frequently mis-understood. The terms “verified” and “validated” also occasionally cause some confusion. We briefly define these terms below in line with the European Cooperation for Space Standardization (ECSS) [9] definitions:

- Verification is the “process which demonstrates through the provision of objective evidence that a product is designed and produced according to its specifications”. Hence following verification, a product is deemed “verified”.

- Validation is the “process which demonstrates that the product is able to accomplish its intended use in the intended operational environment”. Verification is a pre-requisite for validation.

- Qualification is “that part of verification which demonstrates that a product meets specified qualification margins”.

Therefore, “verification” and “validation” activities are associated with a lubricant product but the term “qualification” is reserved only for the space mechanism that uses the lubricant product (it is the mechanism to which the customer requirements are applied and for which the margins must be demonstrated). This distinction is further confirmed in the ECSS materials, mechanical parts and processes standard [10] which mandates that lubricants shall be treated as materials i.e. “raw, semi–finished or finished substance (gaseous, liquid, solid) of given characteristics from which processing into a component or part is undertaken”, and critically: “Materials are validated. Mechanical parts are qualified. Processes are verified”.

ECSS is clear that a lubricant cannot itself “be qualified” and so cannot be generically and widely adopted without risk. However, a mechanism that employs a certain lubricant may be subjected to a successful qualification test campaign, and so become a “qualified mechanism”. The lubricant it contains will then have been fully validated for use <u>within that specific, single mechanism application under the specific conditions tested</u>. Importantly: a single, successful mechanism qualification does not imply there is a reduction in the risks associated with the use of its lubricant in a subsequent application. However, over time, if the lubricant is used across a range of space mechanism applications, an increasingly broad envelope of conditions may emerge where the lubricant has been validated, and for operation within this envelope there is some reduced risk.

Paradoxically then, though many lubricants have been used in mechanism qualification models that have been qualified, no lubricants are “qualified lubricants” – lubricants are only validated, so any supplier that claims their lubricant “is qualified” is, strictly speaking, incorrect – it is the mechanism which is qualified.

Given the above, it is clear a new lubricant shall first be verified, then validated and only after a comprehensive review of the initial lubricant validation data shall it be proposed for adoption in a mechanism, which will be the subject of a qualification campaign that completes the validation of the lubricant for a single application.

Therefore, though this paper highlights our “Guidelines for Qualification" document, in fact, the definition of the actual mechanism product qualification test campaign will be at the discretion and subject to the mutual agreement of the mechanism developer/supplier, customer and relevant Agency. Rather, the guideline document simply seeks to define the minimum pre-requisite steps required and ESA's expectations concerning available data for any new fluid lubricant which is slated to be included in a qualification campaign by offering:

- A standardised definition of the lubricant process verification data expected.
- A standardised definition of the lubricant validation tests expected (e.g. tribometer or component level tests).
- A reconciliation of the new approach to heritage fluids (to avoid the possibility that this new standardisation of approach might negatively impact heritage space lubricants, which may already have been validated in a wide range of qualification campaigns for numerous applications).

The remainder of this paper outlines the above process steps and the requirements at each stage.

3 PROCESS OVERVIEW

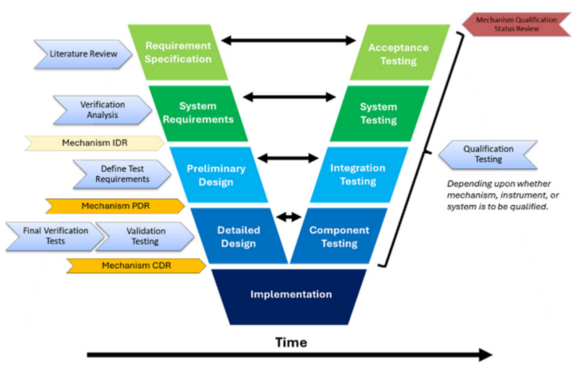

Figure 1. Mechanism Development V-Model

The process flow shown in Fig. 1 maps the key activities foreseen in the guideline to a systems engineering V-model of a typical mechanism or system development programme familiar to many readers. The main elements of the process can be seen on the left side of the V which shows that a lubricant selection, literature review and some analysis are advised even prior to any kind of company level mechanism Internal Design Review (IDR); that additionally lubricant verification and validation tests are intended for completion prior to a mechanism Preliminary Design Review (PDR) and that remaining lubricant verification and validation tests are to be completed prior to mechanism Critical Design Review (CDR).

When the mechanism (including the new lubricant) completes its qualification at some level (see right hand side of V) a final Mechanism Qualification Status Review will approve all aspects required for flight use.

3.1 Prior to Mechanism PDR

The following three activities are envisaged pre-PDR:

<u>Literature Review:</u> This gathers data on lubricant testing, safety, manufacturing, compatibility, handling, storage, cleaning, viscosity, and evaporative losses. It supports identification of a pool of candidate lubricant options and their assessment/trade-off, ultimately narrowing the pool to one or two candidates based on application requirements.

<u>Verification Analysis:</u> in relation to the top-level mechanism requirements, an analysis of the evaporative losses, lubricant regime, and bearing torque must be conducted. At this stage, any tribometer level verification tests will be carried out which are needed to show, in principle, that the lubricant(s) under consideration is (are) appropriate for the application. This analysis may also support down-selection amongst multiple lubricant options.

The above two activities should ideally be completed prior to any Internal Design Review (IDR) for minimum programme risk.

<u>Test Requirements Definition:</u> in which verification data is reviewed and compiled into a preliminary "Lubricant Product Dataset" (LPD) document. In preparation for PDR any verification test data gaps are identified, the possible lubrication options ranked (if applicable), and the lubricant validation and mechanism product qualification testing requirements are outlined.

3.2 Mechanism PDR

At mechanism PDR, the available lubricant verification data will be assessed, and plans for further verification, and validation tests, together with preliminary mechanism qualification will be reviewed and agreed.

If no clear lubricant trade-off winner is identified at PDR, the ranking and logic for finalisation of the selection must be presented and agreed by all parties.

3.3 Between Mechanism PDR and CDR

After mechanism PDR any outstanding verification tests are completed to enable the minimum verification data set which will be presented at CDR to be finalised, and any specialised fluid property (verification or validation) tests are conducted.
Though multiple lubricant options may remain under

consideration after PDR, in practice, the programmatic timeline, and costs, will likely force a lubricant baseline to be selected at PDR, with "alternative" options remaining only as a backup. The baseline and any alternative lubricants may be subjected to verification and /or validation tests post-PDR to provide supporting data to confirm the baseline choice.

Validation testing, for example comprising in-vacuum tribometer and component level tests may be conducted at this stage. Once any critical test milestone is reached, a lubricant assessment meeting will be convened to agree the baseline and confirm the remaining validation data expected at CDR, at which time all findings are consolidated into a full LPD document and a "Lubricant Product Specification" (LPS).

3.4 Mechanism CDR

At CDR all lubricant data will be reviewed, and authorisation will be provided (or not) to include the lubricant in the mechanism qualification test campaign, which will follow.

3.5 Post - Mechanism CDR

After CDR and hardware manufacture, the mechanism product qualification test campaign is executed, findings reviewed, and a "Lubricant Qualification Matrix" produced for approval at the mechanism Qualification Status Review meeting.

The rest of this paper summarises the specific lubricant verification and validation steps envisaged.

4 LUBRICANT VERIFICATION

Verification of a fluid lubricant production implies the lubricant is produced using established (fixed/frozen) processes and process inputs, and that after production an objective dataset of verification data is available showing that the properties of the lubricant produced are in-line with specification (preferably by reference to defined objective acceptance criteria, or batch "in-family" criteria for more subjective assessments (e.g., colour or FTIR spectra in the absence of contaminants)).

The typical repeatability of lubricant characteristics within and between manufactured batches should also be assessed when the product is re-manufactured to identify acceptance criteria. Hence it is recommended that where possible, at <u>least two batches of a lubricant should be produced (from two sets of manufacturing inputs) to complete verification.</u> By this process the specification is refined and the allowable tolerances on parameters defined.

4.1 Verification Tests

Verification testing is carried out primarily to ensure lubricant production consistency, and wherever possible includes assessments of parameters considered to be standard to the industry. For <u>oils/base oils</u>, the mandatory tests include:

- Density / Specific Gravity: can impact the fluid flow behaviour and must be known to confirm use of target lubrication volumes.
- Pour Point: measures the lowest point a fluid may readily flow/function properly as a fluid lubricant.
- Viscosity: measures the resistance of a fluid to deformation under a shear stress.
- Viscosity Index: an arbitrary number, defining the lubricant's viscosity as a function of temperature.
- Molecular Weight: the average molecular weight must be known for evaporative loss calculations (though molecular weight distribution can be used in more specialised analysis, presently its measurement is not mandatory).
- Evaporation: the loss of volatile constituents of the oil occurs both under vacuum and in air environments. However, even a standard test in laboratory air can readily aid understanding of the lubricant evaporation stability, and/or the potential volatile contaminants in a lubricant.

The additional mandatory industry standard tests required for <u>greases</u> include:

- Penetration: standard penetration tests shall be used to determine the grease consistency, indicating the correct lubricant mixture and ensure the grease "viscosity" properties required for the application.
- Dropping Point: an assessment of the temperature at which the grease loses cohesiveness, that (alongside the chemical degradation temperature of the grease) determines its upper operating temperature.
- Oil Separation: measures the separation of the base oil, at elevated temperature, from a grease that can result in a change in consistency of the product and potentially the ability of the grease to lubricate.

The potential for contamination is a critical concern of the space industry, hence for both a base oil and a grease product the following tests are also mandatory for any batch or lot produced:

- Particulate Contamination: which can be measured using microscopy techniques.
- Fourier Transform Infra-Red (FTIR) Spectroscopy: to confirm both the absence of

unwanted materials and maintenance of correct product chemistry.

Finally, there are several space-industry-specific tests that, should ideally be conducted on two batches of a candidate lubricant and may even be regularly assessed as part of the lubricant product assurance:

- Outgassing: assesses release of gaseous species and vapour from a specimen under vacuum conditions (includes absorbed moisture/oxygen as well as volatiles from the lubricant itself). Of critical concern for contamination sensitive applications.
- Vapour Pressure: is critical to evaluating the expected evaporative losses in a system and therefore optimising the mechanism lubrication. The ESA (TEC-QEE) Vacuum Balance Quartz Crystal facility should be baselined for definitive absolute measurements. Alternative methods may only be appropriate for quality assurance purposes.
- Tribometer Level Testing: both ESA and NASA have found the spiral orbit tribometer (SOT) to provide a high degree of repeatability in assessing tribo-chemical degradation of lubricants and thus the SOT has become a standard part of space fluid lubricant analysis.

5 VERIFICATION PROCESS STRESS TEST

In order to "stress test" the Issue 1 process, ESTL was asked to identify two lubricants for which to consolidate the needed data as far as possible. After review of several candidates, the lubricants finally chosen were BP Castrol's Braycote 601 EF and Materiales' Formulation J, representing highly mature and novel lubricants respectively. For these products, manufacturer's data (where tested in accordance with the preferred methodology) and data from dedicated ESTL tests (where appropriate pre-existing data was not available) were consolidated together [11, 12]. The guideline requires that product data relevant to the lubricant selected shall be compiled into an LPD document. The LPD is intended to provide generic information on the fluid lubricant properties and to provide a basis for the derivation of a LPS document, which provides key properties and expected tolerances to control future procurement of the lubricant whenever a new batch (or lot) of lubricant is obtained.

During the stress test exercise LPD and LPS documents were produced for both lubricants evaluated. These documents not only provide all the needed information for PDR in a standardised form but allow easy comparison between the candidate products for a given mechanism application as shown in Tab. 1 which merges extracts from the LPDs produced.

Table 1. Lubricant Product Dataset Extract for BP Castrol's Braycote 601 EF and Materiales' Formulation J

Description	Method	Units	Value(s)		Value(s)
Base Oil			**Brayco 815Z**		**Fomblin Z25 / Fomblin YR-1800 blend**
Density / specific gravity	D287	-	1.85 at 16°C		1.87 at 15°C
Pour point	D97	°C	-72		-71
Viscosity	D445	cSt	9898 at -54°C		941 at 0°C
			134 at 38°C		174 at 40°C
			41 at 99°C		34.5 at 100°C
Viscosity index	D2270	-	348		242
Molecular weight & distribution	UNK	g/mol	17,100 mean (distribution UNK)		17,100 / 7300
					(Z25 / YR-1800)
Vapour pressure	Knudsen /VBGC	Pa	Knudsen		VBGC
			5.32e-11 at 20°C		(Z25) 2.13e-13 at 20°C
			2.66e-7 at 100°C		(Z25) 3.73e-9 at 100°C
			2.66e-4 at 200°C		
Formulated lubricant			**Braycote 601 EF**		**"Formulation J"**
Component and Process	-	-	PTFE particles		PTFE particles
			dry mixed into oil		solvent mixed into oil
Life and Storage	-	-	10 years in a sealed container in a cool, dark ambient environment		Not defined currently
Appearance	-	-	Smooth, buttery, translucent, off-white		Smooth, buttery, translucent, off-white
Evaporation	D2595	% weight	0.9 over 22hrs at 204°C		0.68 over 22hrs at 200°C
Outgassing	ECSS-Q-ST-70-02	% weight	TML = 0.06		TML = 0.16
			RML = 0.05		RML = 0.12
			CVCM = 0.01		CVCM = 0.03
Spiral Orbit Tribometry (SOT) Life	-	orbits/μg	231		289
			154		239
			208		269
Grease specific tests					
Grease penetration	D217	0.1mm at 25°C	Unworked = 288		Unworked = 260
			Worked = 290		Worked = 281
Dropping point	D2265	°C	213		200
Oil separation	D6184	% weight	10.53 over 30hrs at 204°C		8.0 over 30hrs at 204°C
			-		7.1 over 22 days at 100 °C

6 LUBRICANT VALIDATION

A lubricant lot/batch which has been verified to be within specification (as a pre-requisite) shall then be exposed to a validation test campaign to provide objective evidence of its suitability within the intended operating environment.

Validation tests therefore must be conducted in-line with space-industry relevant standards and established test methodologies, but perhaps need to be conducted only in a single campaign prior to qualification.

Lubricant validation involves testing a verified batch to demonstrate suitability for space environments, following relevant standards. Tests include tribometer and component-level assessments under thermal vacuum conditions, simulating real operating parameters for the intended application. Validation is tailored per mission and defined at PDR, but does not equate to full qualification, which remains application-specific.

Validation tests may encompass a wide range of parameters including physical tests (e.g., outgassing, radiation resistance etc.) as well as tribometer level tests and component/unit level tests (e.g. tests of ball bearings or gears). Tests shall include simulated on ground operation in air (as appropriate) and under appropriate thermal vacuum conditions covering the range of lubrication conditions expected in the application i.e. temperatures, contact stresses, and speeds etc. The extent of validation testing required shall be agreed between the mechanism supplier and the Agency. If necessary, validation may focus on the requirements of a first qualification mission only (rather than all missions of the intended mechanism product portfolio), with later mission validations added over time.

Upon successful completion of the validation test campaign the lubricant is NOT fully validated or "qualified". In general, validation testing may be fully generic and potentially fully independent of any target mechanism application. However, some risks may remain for lubricants, for example extrapolation to larger size bearings, different speeds, long term storage risks, which may not be retired easily. Qualification of a specific mechanism that is lubricated by the product is a separate, final step in the sequence and provides full lubricant validation for the target application.

7 OTHER TESTING

In addition to the required tests, if relevant, additional tests to identify application specific properties may be requested by the Agency including, but not limited to:

- Dielectric breakdown potential
- Material corrosion tests
- Rocket fuel or other chemical compatibility
- Creep barrier compatibility
- Ionising radiation tolerance
- U.V. exposure resistance
- Surface energy assessment

It is interesting to note there are several standard tests, which are not generally applicable to space lubricants, and so not required. These include fretting wear or 4-ball wear tests, terrestrial material corrosion tests, and potentially also oxidation stability.

8 INDUSTRY AND STRESS TEST FEEDBACK

In response to industry feedback. and as a result of the observations made during the process stress test that ESTL carried out, the number of tests required during verification has been reduced where possible. Major cost elements, such as the requirement to manufacture at least two batches of the lubricant and carry out several high-cost tests (e.g. vapour pressure assessment) on both batches in all cases are no longer mandatory. The main changes implemented in the Guideline for Issue 2 are summarised below:

- A specific lubricant Characterisation stage (a part of verification) has been introduced. This simply describes the tests to be done on a single, first batch of a new lubricant (distinct from batch verification which must be done on all newly manufactured batches) and essentially generates the "catalogue data".
- The requirement for a second batch manufacture and test is no longer mandatory in all cases and now discretionary at the behest of ESA.
- Vapour pressure measurement is now to be assessed, preferably on the formulated lubricant, at the Characterisation stage, but may in specific circumstances be required at the later Validation stage too, mainly in cases where large batch-to-batch variations are seen (e.g. in FTIR) or for applications which are particularly sensitive to evaporation/contamination.
- Particle counts of base oil and evaluation of particulates in formulated greases are now only required per batch at the Characterisation/ Verification stage (and responsibility of the supplier), rather than at the Lot Acceptance/Verification stage.
- The total number of recommended Lot Acceptance/Verification tests is reduced to two – only a visual check and FTIR are now mandated. FTIR analysis is recommended as part of the Lot Acceptance Test for which the mechanism engineer is responsible because it is a relatively low-cost and readily available analysis. Measurable differences in the intensity of the peaks within FTIR spectra from different lubricant Batches or Lots (or indeed a single Lot over time) might indicate a shift in the molecular mixture present in the fluid, a fundamental change in the lubricant chemistry or the presence of a contaminant.
- Specific measures and a classifcation system have been introduced for cases where a lubricant has some prior space or terrestrial vacuum heritage, or is under assessment at the time of introduction of the guidelines, but potentially has insufficient objective data to fully meet the requirements introduced. In such cases aspects of the process may be waived at the disrection of ESA.

9 TESTING MATRIX ADAPTATION

The updated test matrix required by the guideline document at Issue 2 for a grease is shown in Tab. 2. In the table it is clear that some formerly mandatory tests are no-longer applicable (indicated as N/A).

Table 2. Recommended Verification and Validation Tests for a Grease (from [7])

Test Number	Method preferred	Description	Lubricant Supplier Responsibility: Characterisation[1]	Lubricant Supplier Responsibility: Batch Verification[2]	Mechanism Engineer Responsibility: Lot Acceptance[3] (Lot Verification)	Mechanism Engineer Responsibility: Validation[4]	Mechanism Engineer Responsibility: Qualification
BASE OIL							
1	ASTM D4052	Density /specific gravity	x	x			
2	ASTM D97	Pour point	x	x			
3	ASTM D445	Viscosity	x	x			
4	ASTM D2270	Viscosity index	x	x			
5	FEDSTD791D 3009.3	Particle count	x	x	N/A		
6	--	Molecular weight distribution	x				
7	ESA-DOK	Vapour pressure	x			N/A	
GREASE LUBRICANT TESTS							
8	--	Component and process	x	x			
9	REACH Reg 1907/2006	Health and safety	x				
10	--	Life and storage	x				
11	--	Solvent and chemical compatibility	x				
12	--	Appearance	x	x	x		
13	--	FTIR	x	x	x		
14	ASTM D972	Evaporation	x	x	N/A		
15	ECSS-Q-ST-70-02	Outgassing	x	x			
16	ESA-DOK	Vapour pressure	x			x[5]	
17	--	Other application properties				x	
18	PRA-ESTL-ED-0017	Spiral Orbit Tribometer (SOT) [6]	2x			x	
19	ECSS-E-ST-33-01C	Component level tests				x	
20	ASTM D217	Grease penetration	x	x	N/A		
21	ASTM D2265	Dropping point	x	x			
22	ASTM D-6184	Oil separation	x	x			
23	FEDSTD791D 3005.4	Particulate contamination	x	x	N/A		
24	--	Particulate additive information	x				
MECHANISM, INSTRUMENT OR SYSTEM LEVEL QUALIFICATION TEST							
25	ECSS-E-ST-33-01C	Mechanism qualification tests					x

1 - Done on a single Batch to define the expected properties.
2 - Done on ALL newly manufactured Batches.
3 - Done on each Lot drawn from a verified Batch.
4 -Done on a single Batch only, shows performance of a verified Batch under TV conditions.
5 - Mandatory only for applications where the vapour pressure of the lubricant is critical.
6 - Not expected to be carried out by the lubricant supplier, commissioned by mechanism engineer on 2 batches
N/A – No-longer applicable at Issue 2 of [7].

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10 DOCUMENTATION

Though a preliminary LPD is required early in the process, ultimately it is intended that all relevant product data from all stages of the verification and validation process shall be compiled into the LPD in a generic form which can be shared as a record of the fluid lubricant properties. When the LPD is compiled together with the component /mechanism testing information this becomes a full Lubricant Qualification Matrix (LQM). Although ideally all testing information should be made widely available, it is recognised that the application-specific information likely contained in the LQM may prohibit its wider distribution.

From the LPD it is required to derive an LPS to control future procurement of the lubricant. The LPS is a quality control document which shall apply whenever a new batch (or lot) of lubricant is obtained. This document is to be used to ensure the appropriate lubricant properties are always obtained from subsequent procurements. These guidelines ensure that after the initial mechanism development and lubricant validation, all lubricants used have a full and accessible data set and are provided with a CoA/CoC by the manufacturer which ideally also references the LPS.

11 CONCLUSIONS

This paper provides an overview of the guideline document which has been jointly developed with ESA. It has been adapted in response to comments from industry, stress tested and now presents ESA's expectations concerning the steps needed to introduce a new lubricant into a mission which it oversees.

This means that:

- A lubricant which has been accepted as having met the defined criteria for verification and validation as pre-requisites might ultimately be employed within a mechanism, instrument or system which will be subjected to a qualification test campaign, but lubricants which have not fully met the pre-requisites should not be employed in such campaigns.

- Only upon completion of the necessary verification and validation assessments AND ultimately also a successful qualification test campaign, can a fluid lubricant be deemed suitable for use in flight hardware.

As a final comment, it should be noted that where a lubricant is employed in a successful qualification programme for one mechanism, at best, this fact merely reduces the risks associated with achieving qualification of a further mechanism employing the same lubricant. The concept of a "qualified lubricant, applicable in many applications" is a fallacy – lubricants are to be treated in ECSS terms as "materials" and wide adoption comes from inclusion of a verified and validated lubricant in multiple individual qualification programmes for diverse space mechanisms. According to ECSS-Q-ST-70C: "Materials are validated. Mechanical parts are qualified. Processes are verified".

12 REFERENCES

1. Conley, P.L. & Bohner, J.J. (1990). Experience with Synthetic Fluorinated Fluid Lubricants. 24th AMS, pp 213-222

2. Vernier, C.G. & Casserly, E.W. (1991). Multiply-Alkylated Cyclopentanes: A New Class of Synthesized Hydrocarbon Fluids, Lubr. Engr. 47, 7, pp 586-591

3. Fusaro, R.L. (1994), Lubrication of Space Systems, NASA TM 106392

4. ECHA (2025), Highlights from June RAC and SEAC. Online at *https://echa.europa.eu/-/highlights-from-june-2025-rac-and-seac-meetings* (as of 07/07/25).

5. Nye Lubricants, Inc., Everything You Need to Know About PFAS & Non-PFAS Based Lubricants. Online at *https://www.nyelubricants.com/non-pfas-based-lubricants* (as of 07/07/25)

6. Buttery, M. (2018). Ionic Liquids– Performance as Space Lubricants, ESA-ESTL-TM-0174 01-

7. Kent, A. et al. (2024, 2025). Guidelines for Qualification of New Fluid Lubricants, ESA-ESTL-TM-0375 01-/02-

8. Kent, A. et. al. (2023), Guidelines for Qualification and Space Application of New Fluid Lubricants, *Proc. 20th ESMATS,* Warsaw, Poland. Online at https://esmats.eu/esmatspapers/pastpapers/pdfs/2023/kent.pdf (as of 07/07/25)

9. ESA Requirements and Standards Division, (2012). Glossary of terms, ECSS-S-ST-00-01C

10. ESA Requirements and Standards Division, (2019). Materials, mechanical parts and processes, ECSS-Q-ST-70C Rev.2

11. Simpson, M. (2025). Application of New Fluid Lubricant Validation Guidelines - Lubricant A, Braycote 601EF, ESA-ESTL-TM-0435 01-

12. Simpson, M. (2025). Application of New Fluid Lubricant Validation Guidelines - Lubricant B, Materiales Formulation J, ESA-ESTL-TM-0436 01-

Transmittal and Clearance Form [1]

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