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# Use of Lubricants in the NIF

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July 7, 2006

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This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

*Interdepartmental letterhead*  
*Mail Station L-491*  
*Ext: 2-8093*

July 3, 2003  
NIF-0070329-OC

**TO:** File

**FROM:** William H. Gourdin and Peter Biltoft

**SUBJECT:** Use of Lubricants in the NIF

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**ISSUE:**

What are the constraints on the use of lubricants in various environments within NIF?

**BACKGROUND:**

There are two principal concerns that govern the use of lubricants in NIF:

1. *Airborne molecular contaminants* (AMCs). AMCs are known to seriously degrade the performance of sol-gel coated optics. AMCs are produced by the slow outgassing of residues (non-volatile residues or “NVRs”) of high molecular weight compounds left on surfaces. Lubricants, particularly hydrocarbon lubricants, are a primary source of such NVRs
2. *Particulates*. Particulates that accumulate on optical surfaces can cause permanent physical damage when exposed to high energy density laser light. Lubricant residues exposed to high energy density light will pyrolyze or decompose and produce carbon particulates.

The NIF Approved Materials Database<sup>1</sup> lists several lubricants that have been tested for use in NIF environments. Many of these lubricants were tested according to MELs 99-006<sup>2</sup> (oven outgassing test) or 99-007<sup>3</sup> (vacuum outgassing test). In these tests, the change in percent transmission of light through a sol-gel coated optic placed next to the sample under evaluation is used as the diagnostic. Samples that cause less than 0.1% change in optical transmission are deemed suitable for use inside beam enclosures. This testing, however, addresses only the concern associated with AMCs. To assess the issue of particle generation, a flashlamp or “aerosol” test is used. In this test a sample with residues is subjected to intense light from the main amplifier flashlamps. The number

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<sup>1</sup> Available at the LLNL web site, <http://materials.llnl.gov/>. See NIF0083090, “NIF Approved Materials Database and materials approval protocol” for more information.

<sup>2</sup> NIF5002867, *Elevated Temperature Qualification of Low Outgassing Materials for NIF*.

<sup>3</sup> NIF5005535, *Vacuum Qualification of Low Outgassing Materials for NIF*

density of particles per unit volume is measure after each flash. A measurement of an average of fewer than 1000 particles  $>0.5\mu\text{m}$  in diameter produced per square foot of exposed surface per flash for each of the last ten flashes in a series of 60 flashes of light is deemed to be acceptable for polymers<sup>4</sup>. A measurement of an average of fewer than 100 particles  $>0.5\mu\text{m}$  in diameter produced per square foot of exposed surface per flash for each of the last ten flashes in a series of 60 flashes of light is deemed to be acceptable for metals<sup>4</sup>.

The quantity of NVRs allowed in various parts of NIF is specified in terms of mass per unit area, usually referenced to "level A" which is defined<sup>5</sup> as  $1\text{ mg/ft}^2$ . Precision cleaned portions of NIF, including the beamline, must be no higher than A/10, or  $0.1\text{ mg/ft}^2$ , of detectable NVRs when accepted from the precision-cleaning subcontractors<sup>6</sup>. When commissioned<sup>6</sup>, these same parts can have NVRs no higher than A/3, or  $0.33\text{ mg/ft}^2$ . At these levels of cleanliness, the effects of AMCs and particulates are deemed to be negligible. However, some mechanisms within precision cleaned portions of NIF have moving parts that must be lubricated. Several of the NIF-approved lubricants have vapor pressures that are so low ( $<10^{-12}$  Torr at  $20^\circ\text{C}$ ) that AMCs are not a concern. Inadvertent spread of residues from lubricated surfaces to surfaces that may be exposed to laser light, however, could occur.

Most of the approved lubricants are made from fluoro-carbon oils<sup>7</sup> thickened with sub-micron Teflon® (PTFE) particles or other non-volatile ingredients. Hence, the vapor pressure of the lubricant is approximately that of the base oil from which it is made. As a result, if a thickened lubricant such as grease is approved for use on the NIF, the base oil from which it is prepared is also acceptable. For example, DuPont Krytox™ XHT-ACX grease (formerly known as LVP-228) passed the oven outgassing test<sup>8</sup> and is approved for use in the NIF precision-cleaned beampath. The oil from which it is made, Krytox™ XHT-750, is therefore also approved<sup>9</sup>. The viscosity of the base oils generally increases as the vapor pressure decreases, so lubricants with very low vapor pressures are often very viscous (400-1000 cSt).

**ASSESSMENT:**

Precision cleaned portions of the NIF beamline must be kept free of all NVRs, including residues from lubricants, to the specified level, usually A/10, as cleaned, A/3 when installed. Residues from fluoro-carbon lubricants can only be removed with difficulty using special solvents. Normal precision cleaning processes are ineffective with these materials; hence it is imperative that lubricants in the beamline be used in such a manner

<sup>4</sup> NIF5010984, MEL01-017-OA, "Flash Lamp Testing of Polymers, Metals and Ceramics," C. Petty, C. Alviso, I. F. Stowers, November 12, 2002.

<sup>5</sup> *Military Standard Product Cleanliness Levels and Contamination Control Program*, MILSTD-1246C, April 11, 1994.

<sup>6</sup> C. Marshall, NIF-0063552, March 26, 2001

<sup>7</sup> Perfluoropolyethers, abbreviated PFPE.

<sup>8</sup> NIF0073131, "Material Testing Database for NIF," tab 2, record 183.

<sup>9</sup> A second oil, Krytox™ 16256, from which LVP-228 was made previously, is also approved. It differs slightly from XHT-750 in chemistry, but has identical performance properties.

that precludes to the greatest extent possible their spread. In particular, the casual use of lubricants (e.g. for lubricating the threads on bolts) during assembly of precision-cleaned parts is not prudent because the possibility transferring residues that may be exposed to high energy density light is too great. When used to lubricate mechanisms or other essential components, approved lubricants should be sealed, shielded or otherwise protected so that the lubricant cannot be transferred to other surfaces and will not be exposed to intense light. Exposed un-lubricated surfaces of such mechanisms must meet the cleanliness specification for the environment in which they are used.

Non-precision-cleaned portions of NIF<sup>10</sup> are generally less sensitive to the possible effects of AMCs associated with lubricants. The pre-amplifier module (PAM) and the pre-amplifier beam transport system (PABTS)<sup>11</sup>, for example, contain only “hard” dielectric-coated (non-sol-gel coated) optics, which are known to be less sensitive to AMCs than sol-gel coated optics. Similarly, utilities that service the beamline but which will not be exposed to laser light, and areas external to the beamline, including the laser and target area building (LTAB), are of lesser concern. Nevertheless, prudence requires that the use of lubricants be controlled in these areas as well to prevent gross contamination with potential sources of AMCs.

### RECOMMENDATION:

1. Lubricants may be used in precision-cleaned portions of the beampath *only* when they are essential for the proper functioning of mechanisms or components. The only lubricants that may be used for this purpose are ultra-low vapor pressure lubricants specifically approved and placed in the NIF Approved Materials Database<sup>1</sup>. In such applications, a minimum of lubricant shall be used, consistent with proper operation. The lubricant shall be protected from exposure to high-energy density light, either from the laser or the flashlamps. An effort must be made to seal, shield or otherwise protect lubricated parts so that unintentional transfer to other surfaces does not occur during operation or handling. Similarly, during maintenance or installation, procedures must be implemented to preclude unintentional transfer of lubricants to surfaces where they are not wanted. The un-lubricated parts of assemblies that contain lubricants must meet the cleanliness specification for the environment in which they are used.
2. Casual use of lubricants (e.g. for lubricating parts as an aid to assembly) is *not allowed* in any precision-cleaned portion of NIF without prior review and approval. In particular, lubricants shall not be used on the interior surfaces or environments of precision-cleaned beampath and utility components, except as stated in item 1. If lubricants are approved for use as an assembly aid, procedures must be implemented to minimize their transfer to surfaces where they are not wanted and a plan must be developed to remove residues, should that be necessary.

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<sup>10</sup> K. Manes, I. Stowers, C. Marshall and D. LaTray, “Recommended cleanliness requirements for fabrication, installation and operations of the PAM, ISP, PABST, OSP and Lower Injection System,” NIF0079873, March 28, 2002.

<sup>11</sup> W. H. Gourdin, “Cleanliness requirements for the PAM/PABTS,” NIF0068482, August, 2001.

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3. Lubricants approved for lubricating mechanisms in the beampath may also be used in non-precision-cleaned environments (e.g. the PAM and PABTS<sup>12</sup>). A minimum of lubricant, consistent with proper operation, shall be applied to lubricated parts and the lubricant shall be utilized in such a manner as to minimize unintentional transfer to other surfaces.
4. Lubricants approved for lubricating mechanisms in the beampath may also be used in the LTAB environment.
5. Lubricants other than those approved for lubricating mechanisms or components in the beampath may not be used anywhere in NIF without explicit review and approval. Once reviewed and accepted, they may be used only for the application and environment for which they are approved. Use in any other environment will require additional review.

cc:

Cleanliness Steering Committee members

Peter Biltoft

John Ertel

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<sup>12</sup> William H. Gourdin, "*Cleanliness requirement for the PAM/PABTS*," NIF-00068482, July 26, 2001, adopted by the NIF Cleanliness Steering Committee on July 27, 2001

# Use of lubricants in NIF

