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Development of an EPU Vacuum System Using Lumped NEG-Ion Combination Pumps

Nonevaporable getter (NEG) coatings and NEG strips[1] have been extensively used as pumping solutions in synchrotron facilities to address the problem of conductance limitation on pumping speeds in small-aperture insertion device (ID) vacuum chambers. Applying an NEG coating to accelerators is a complex technique that requires technical expertise and substantial upfront investment for the manufacture and operation of a NEG-coated vacuum system; for example, technical expertise is necessary for determining the cleaning processes, coating parameters, activation methods, and neon venting for interventions. For NEG strips (**Fig. 1**), the beam duct must be equipped with an antechamber that houses the NEG strips and their accessories for activation (*i.e.*, alumina supports, aluminum supports, and electrical feedthroughs). A narrow antechamber hinders NEG strip installation, which may generate microparticles caused by friction during NEG strip insertion into the antechamber. To simplify the design and manufacture of ID vacuum chambers and to facilitate installation and maintenance tasks, this study developed a new vacuum design[2] that entails the use of five small lumped ZAO NEG pumps (CapaciTorr Z 200 × 2 and

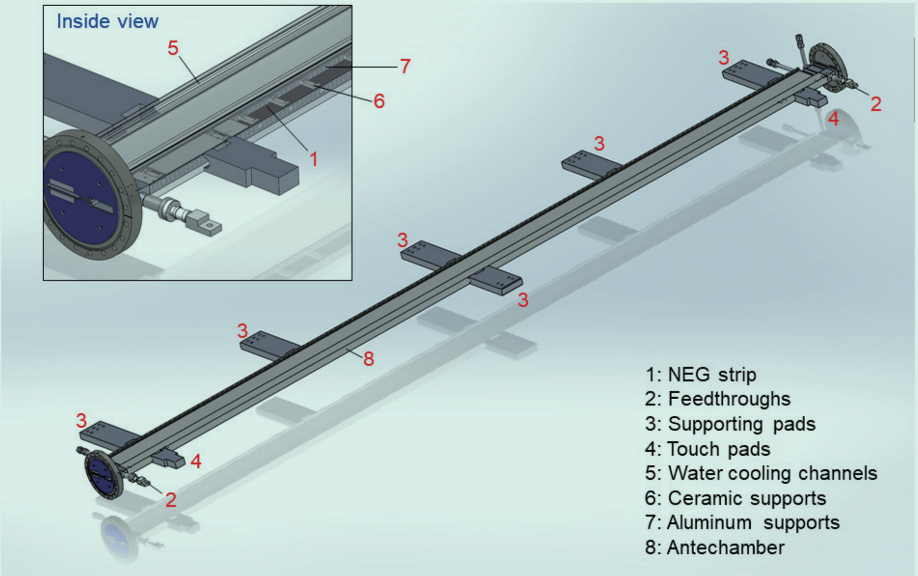

Fig. 1: NEG strip-type vacuum system (5-m length) and its inside view. [Reproduced from Ref. 2]

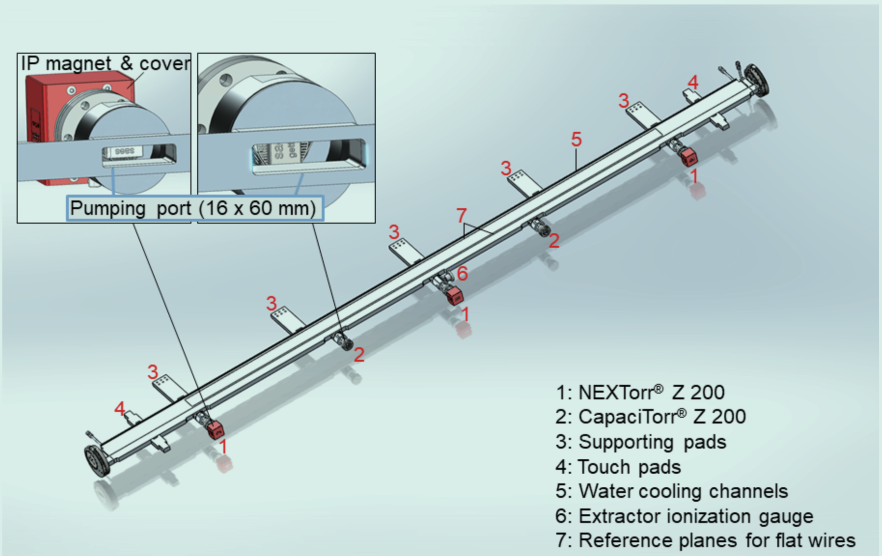

Fig. 2: NEG cartridge-type vacuum system (5-m length) and cross-sectional views of the NEXTorr and CapaciTorr pumps. [Reproduced from Ref. 2]

NEXTorr Z 200 × 3), as illustrated in **Fig. 2**, and implemented this design to construct a vacuum system for an elliptically polarized undulator (EPU). The proposed vacuum design possesses the following features and advantages compared with a previous design:

1. The design includes an extractor ionization gauge located at the center of the EPU chamber; it can accurately measure the pressure inside the chamber.

2. It includes a NEXTorr pump—a small, lumped NEG-ion combination pump—that pumps gases that cannot be absorbed by the NEG alone, including noble gases and methane.

3. It includes a ZAO NEG alloy (Zr–V–Ti–Al) that affords a faster pumping speed, a larger absorption capacity for all active gases, and less outgassing during NEG activation compared with a previously used St707 getter (Zr–V–Fe).

4. It includes two flat wires that are composed of flexible printed circuit boards laminated with Kapton foils on both sides (thickness 1.2 mm) and glued onto the upper and lower surfaces of the EPU chamber; the wires can correct the dynamic multipoles induced by the EPU.

To evaluate the performance of the proposed vacuum design, this study constructed and tested two NEG cartridge-type vacuum systems. The tests included measuring the base pressure upon activation of the NEG pumps without baking, conducting a pressure-rise test by turning off the ion pumps (IPs), and measuring the dynamic pressure as a function of accumulated beam dose.

The major difference between NEG cartridge-type and NEG strip-type vacuum systems is that NEG cartridge-type vacuum systems comprise three small diode IPs and each ion pump has pumping speeds of 6 and 15 L s^{-1} for argon and methane, respectively. This study evaluated the effect of the IPs on the vacuum pressure of the EPU chamber by turning off all of the NEXTorr IPs for 18 h and recording the corresponding increase in vacuum pressure, as displayed in **Fig. 3**. The vacuum pressure after IP shutdown (*i.e.*, pumping with only NEG) increased by approximately 55 times from 3.30×10^{-11} to 1.83×10^{-9} mbar (A in **Fig. 3**). Monitoring results obtained using a residual-gas analyzer (B in **Fig. 3**) indicated that the rise in pressure was attributed to the major gaseous species H_2^+ (m/z = 2), He^+ (m/z = 4), CH_4^+ (m/z = 16), Ar^{2+} (m/z = 20), CO^+ (m/z = 28), Ar^+ (m/z = 40), and CO_2^+ (m/z = 44), as presented in **Fig. 4**. These data indicate that despite their

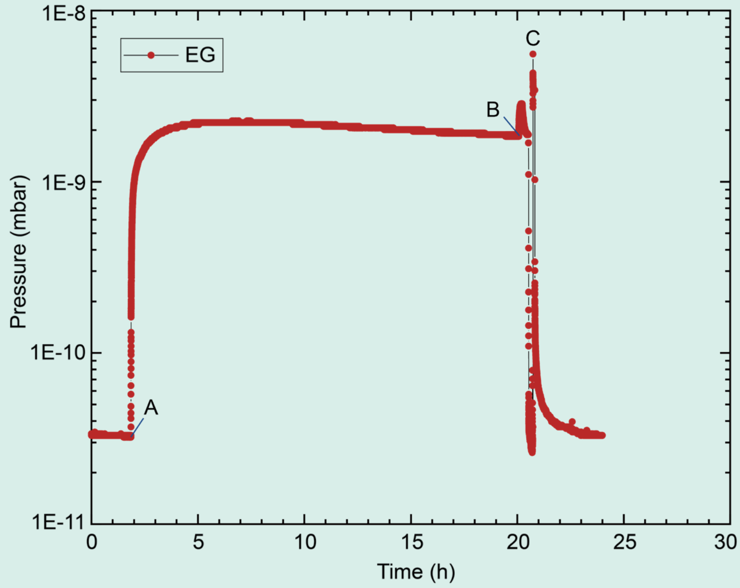

Fig. 3: Pressure-rise curve of the NEG cartridge-type vacuum systems. [Reproduced from Ref. 2]

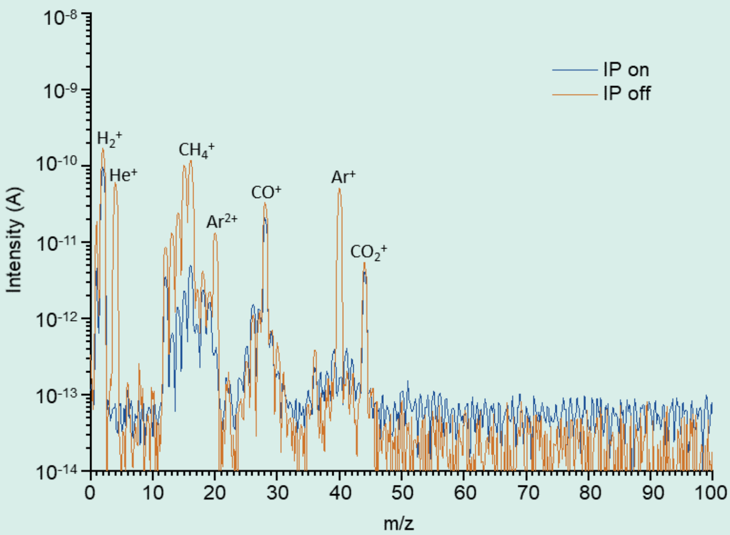

Fig. 4: Gas compositions inside the NEG cartridge-type vacuum systems, as measured using a residual-gas analyzer after 18 h of shutdown of the ion pumps. [Reproduced from Ref. 2]

modest pumping speed, the small IPs acted as auxiliary pumps to effectively regulate the vacuum pressure of the EPU chamber. The chamber pressure rapidly returned to its original level after the IPs were restarted (C in **Fig. 3**)

During a long shutdown in September 2020, the two NEG cartridge-type vacuum systems were installed in the Taiwan Photon Source (TPS) storage ring for two insertion devices, namely EPU66 and EPU168. The vacuum chambers were pumped down to a pressure of $< 1 \times 10^{-6}$ mbar in 5 h, and the NEG pumps were subsequently activated. After NEG activation, the chamber pressures quickly declined to approximately $< 1 \times 10^{-8}$ mbar within hours, as illustrated in **Fig. 5** (see next page). Notably, many gaseous molecules

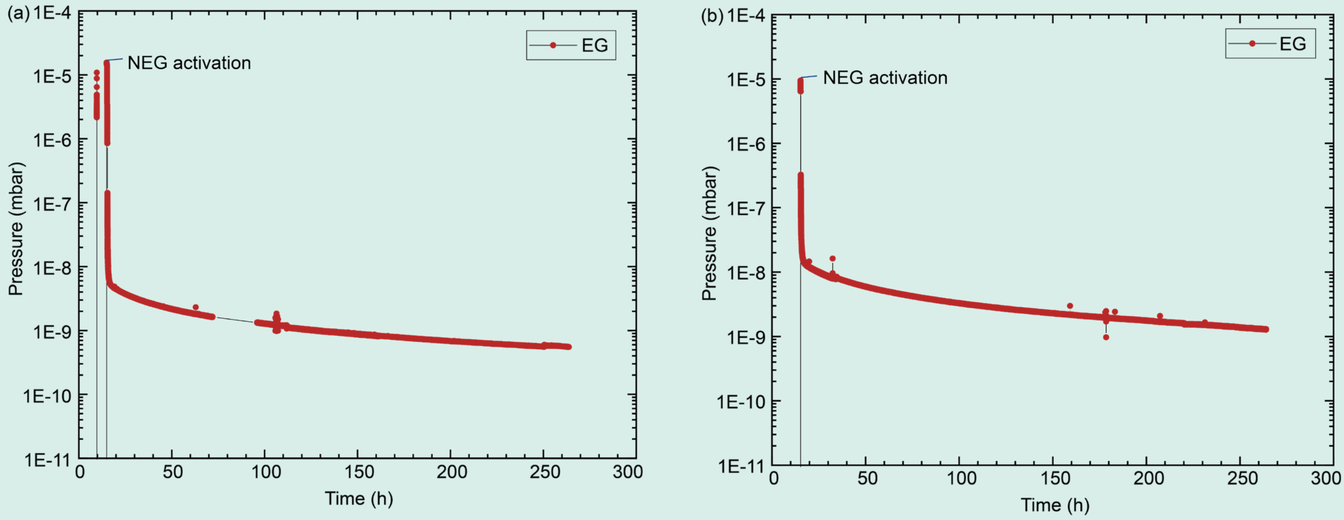

Fig. 5: Pumping curves of the NEG strip-type vacuum systems for (a) EPU66 and (b) EPU168 after NEG activation without baking. [Reproduced from Ref. 2]

released from the getter materials could considerably increase the vacuum pressure during activation. The ZAO NEG alloy mitigated outgassing during thermal activation, which led to a small rise in pressure (< 2×10^{-5} mbar). After pumping for 10 days, the pressures reached 5.5×10^{-10} mbar for EPU66 and 1.3×10^{-9} mbar for EPU168. Because these two EPU chambers were new, and did not receive beam cleaning and bakeout after installation in the TPS tunnel, a beam-scrubbing treatment with synchrotron radiation was applied to improve their dynamic pressures. The dynamic pressures of the EPU66 and EPU168 chambers reached 6.3×10^{-13} and 2.3×10^{-12} mbar mA^{-1}, respectively, after the application of an accumulated beam dose of 100 Ah, as shown in **Fig. 6**. The beam-cleaning data revealed no obvious discrepancies between the baked and unbaked vacuum systems.[3] Therefore, synchrotron radiation alone is sufficient for conditioning NEG cartridge-type vacuum systems; baking is not necessary. (Reported by Che-Kai Chan)

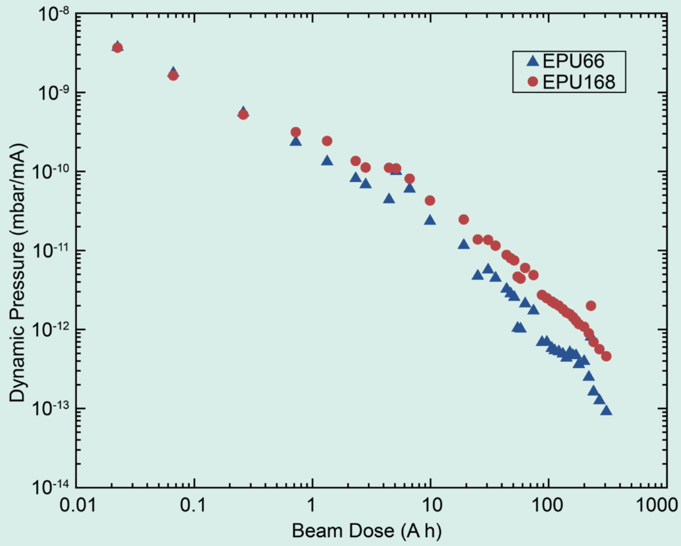

Fig. 6: Dynamic pressures of the NEG strip-type vacuum systems for EPU66 and EPU168 as a function of accumulated beam dose. [Reproduced from Ref. 2]

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