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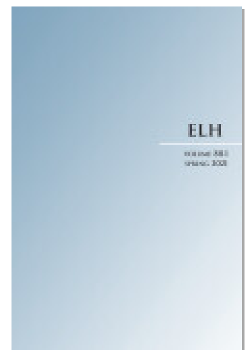

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THE RISE OF THERMODYNAMICS: MECHANICAL ENGINEERING AND BYRON'S POETIC MACHINERY

BY ANDREW BARBOUR

"If it is necessary to find a virtue in technology," Paul de Man remarks in "The Temptation of Permanence," "it is that it is too rude to offer even a simulacrum of appeasement."[1] As it "burns history without leaving material residue, technology forces us to rid ourselves of what is only after all a false serenity," the temptation of permanence.[2] If de Man's tropic language turns away from technology—too rude—it at once turns towards its mechanical power to burn through any illusion of material permanence, with or without residue. As will become clear, de Man's notion of technology burning history implies a historical consciousness of the thermodynamic logic of machinery that emerges out of the steam engine and is now burnt into Anthropocene history, often dated to James Watt's 1784 patent of the steam engine, also known in Lord Byron's time as the fire engine.[3] Thermodynamics arises out of late 18th- and early 19th-century mechanical engineering—leading up to Sadi Carnot's 1824 reflections on the fire engine—as a figure for the dissipation of human mechanical power and the impermanence of the material universe.[4] Much recent work in Victorian studies has attended to the figurative resources of thermodynamics; yet its Romantic origins and impact on Romantic aesthetics have received little attention. I begin by recovering the thermodynamic logic of machinery in Romantic era engineering and painting over the 1810s-20s, culminating in the work of J. M. W. Turner and Carnot. Next, taking a closer look at the rise of thermodynamics in Romantic poetics, I turn to Byron as a case study to recover the engineering poetics that he develops around 1820 as he pioneers a new thermodynamic logic of poetic machinery. I close by reflecting on the critical value of Byron's thermodynamic logic of machinery for Anthropocene thought today. The first aim of this essay, then, is to recover a neglected history of the emergence of modern engineering in the Romantic period, and its thermodynamic aesthetics. My second aim is to demonstrate how the rise of modern engineering (in a much more pragmatic form than the Newtonian science it displaced) directly influenced Byron's poetics, as he came to define his poetic vocation as "my post as an engineer."[5] Romantic poetry and engineering shared a thermodynamic aesthetics fueled by a mutual question: what work can we realistically expect material forms to achieve when they operate under strict constraints of perpetual energy loss and unavoidable physical attrition? That question continues to bear on how we approach poetry and machinery today, and what we might anticipate from aesthetics and engineering in the Anthropogenic age that we share with Romanticism.

I. TURNER / CARNOT

Mechanical engineering marks the transition between simple mechanics and thermodynamics: between the perfect world of Newtonian mechanics ordered by rational principles of motion and a world in which nothing is permanent except for change itself. While thermodynamics is formalized in the 1850s, its core principles arise over the time of British Romanticism with the emergence of engineering.[6] Michel Serres writes, "As soon as one can build them and theorize about . . . steam or combustion engines . . . the notion of time changes. The second law of thermodynamics accounts for the impossibility of perpetual motion. . . . Energy dissipates, and entropy increases."[7] With the engine, force passes from the "rationalized" or "mathematical real" (*H*, 58) of Newtonian mechanics—which abstracted from matter to treat the motion of figures as perpetually reversible, unchanged by friction—to matter itself, in which the production and dissipation of mechanical power by friction is evidence of "an unceasing mutual interchange of figure," as one engineer put it in the 1810s.[8] No more transcendence, only material finitude. Engineers over the time of Romanticism discovered what became the first law of thermodynamics, which formalizes the conservation of energy: that energy is neither created or destroyed but translated.[9] The energy concept depends upon the mechanical theory of heat: that all force is materially equivalent to heat or motion. Heat is not a separate substance but simply the effect of motion. Over the late 18th and early 19th century, engineers also discovered what became the second law of thermodynamics, entropy. As Helmut Müller-Sievers sums up, for the "Newtonians, [friction] was a negligible factor, to be analyzed away," while in steam engines, "the production and dissipation of heat through friction became a first step toward a comprehensive theory of thermodynamics."[10] Every motion is frictive, losing heat, leading ultimately to "the inevitable descent of all organization into undifferentiated matter."[11] Heat is not destroyed, but it is nevertheless irreversibly lost through friction: energy becomes more and more dissipated, until the end of all motion. The best that engineering—or any art—can do is struggle against where it all must end, deferring entropy for a time through mechanical power.

Mechanical engineering arises as a profession and discipline in Britain in the early nineteenth century with the steam engine.[12] Yet the Romantic-era engineers who developed the thermodynamic logic of machinery have been neglected, their voices lost along with their aesthetics. How did engineers themselves figure the rise of thermodynamics? Engineering, as one member of the rising class defined it in the 1810s, is the art of "mak[ing] . . . any kind of useful engines or machines" (*RC*, "engineer"): also called "practical mechanics" or "operative mechanics" (*RC*, "machinery"). Engineers were working mechanics with little formal education whose trade was not taught in universities until the 1890s; Newtonians were mathematicians, scientists, and theorists, not machine-builders. Intellectuals with university chairs, Newtonians built no working machines of any kind. Therefore, the Newtonians' and engineers' approach to mechanics were at war from the start. While Newtonians privileged rational, mathematical principles of force abstracted from friction, engineers valued the variable maker's knowledge of building working engines that generate mechanical power—force or energy—over theory. Mechanics, as one engineer defined it in 1815, "treats of the energy of machines."[13] Due to the variations of force, "an engineer must not be tied down by too many maxims" (*RC*, "machinery") because the engine's power is "extremely variable." (*RC*, "steam-engine.") Newtonian's rational mechanics triumphed over working mechanics until the late 18th century, consolidating their social power. The *Principia*, Isaac Newton insisted, was not a treatise on mechanics but rather designed to found "rational mechanics" as the "science" of "motion" on invariable principles that then applied to machinery.[14] For Newtonians, the power dynamic was only supposed to flow one way: Newtonian theorists dismissed the vulgar mechanics of engineers as too materially variable to ever impact the rationally ordered Newtonian universe.

Force itself was melting away the Newtonians' rational principles. Anti-theoretical and anti-philosophical, engineers in the 1810s waged war on rational mechanics through the mechanical power of the engine. The engineer Robert Stuart's *Descriptive History of the Steam Engine*, which he delivered to engineers in the Mechanics' Institute in 1824, is representative.[15] Stuart pointedly notes how the fact that "the little which has been done by learned men on this subject is of no practical mark or likelihood" in machinery demands "the exclusion of merely theoretic disquisition or inference" by Newtonians from his history of the engine.[16] "No 'philosopher' or 'theoretic men,'" Stuart insists, can claim "any part of the honor of being instrumental, even indirectly, in the perfecting of the steam engine."[17] In fact, "[t]here is no machine or mechanism in which the little that [Newtonian] theorists have done is more useless. It arose, was improved and perfected by working mechanics—and by them only."[18] Stuart is right: no Newtonian theorists or philosophers had any part in the rise of the engine, the work of engineers. Mechanical power ran directly counter to Newtonian's class interests buttressed by rational mechanics. No machine better showed the powerlessness of Newtonian theorists. As Stuart reflects in 1824, "Twenty years ago, [the engineer] Hornblower remarked, 'that the most vulgar stoker may turn up his nose at the acutest mathematician in the world, for, (in the action and construction of Steam Engines,) . . . the higher powers of the human mind must bend to mere mechanical instinct;' and the observation applies with greater force now than it did then."[19]

Much as Stuart sketches, over the early 19th century, mechanical engineering eclipses Newton's rational mechanics to give rise to the new thermodynamic logic of machinery. The reason for the eclipse is simple. Building working engines that efficiently generate mechanical power demanded that the practical reality of friction take precedence over theoretical insight, the logic of machinery thermomechanically abrading the fixed lines of rational mechanics from the inside out.[20] While Newtonians dismissed the effects of friction as a "vulgar error," engineers used machinery to publicly challenge rational mechanics, exposing how the Newtonian's demonstration devices failed in practice to predict the mechanical power of working engines—or of any figures in motion—due to thermomechanical friction (*RC*, "friction"). By working with their tools, engineers over the Romantic era discover the material dissipation of force through friction that turns into the basis for the second law of thermodynamics. As one engineer put it: "the subject of friction is of such importance in relation to the construction and use of various machines" that "no engineer" will fail to account for the "loss of power by friction" in "any engine" (*RC,* "friction"). Friction, as engineers came to define it, is "the act of rubbing or grating the surface of one body against that of another, also called attrition": "[f]riction arises from the roughness or asperity of the surface of the body moved on, for such surfaces consisting alternately of eminences and cavities," which "must be both broke and worn off" by thermomechanical abrasion (*RC,* "friction").

Romantic-era engineers discovered that friction dissipated any mechanical power, force forever lost. As one summed up in 1819, "engineers expect in practice" to "lose part of the advantage of their force by the friction, but how much . . . nothing but practice can determine" (*RC,* "friction"). Faced with the rude truth that a great part of the power of any engine is expended in friction, engineers sought to reduce the waste of force. Since friction arises from figures in motion roughly wearing against one another, engineers discovered that friction diminishes as figures become smoother and more polished. Rough motion was more frictive: smooth motion, less. "Hence it follows," one engineer remarked, "that the surfaces of the parts of machines that touch each other should be as smooth and polished as possible" (*RC*, "friction"). Lubrication was key to reducing the friction as machine parts abraded one another. Engineers thus used vulgar materials like oils, wax, resinous bodies, and tallow in engines to lessen the friction.[21] The engine "should be fitted, and kept in contact" with oil to reduce "burning or heating by friction, when in rapid motion" (*RC*, "machinery.")

Yet ultimately the loss of mechanical power by friction was inescapable. As one engineer put it: "There is no such thing as a perfect smoothness in bodies, no machine can move without a mutual rubbing of its parts" (*TM*, 2:17). "No body can be so much polished" to "take away all [friction]": "witness those numerous ridges discovered by the microscope on the smoothest surfaces" (*RC*, "friction"). Every motion was frictive: "Nor can motion be produced without a force impressed" by thermomechanical abrasion, "the force applied to move the body was either wholly or in part spent on this effect" (*RC*, "friction"). Even if "fit as perfectly as art and industry can make them," all bodies will "wear one another:" "constant friction will tend to enlarge the cylinder, and diminish the diameter of the ring, the piston, after some time, would cease to fit" (*RC*, "steam-engine"). No more Newtonian permanence of figure: all figures thermomechanically abrade one another in motion, breaking down in releasing heat. "Friction subsists [even] after the contiguous surfaces are worked down as regular and smooth as possible. . . . Its existence demonstrates an unceasing mutual change of figure" by the "minute and accidental risks of contact," a ruder, rougher materiality of thermomechanical force and its exhaustion that could never be reasoned away (*RC*, "friction"). The thermodynamic logic of machinery that engineers discovered by working with their tools was too rude to offer any temptation of permanence: even if engines were fit as perfectly as art could make them, any mechanical power would ultimately dissipate by the very force that fueled it. Engineers discovered the loss of force due to friction renders perpetual motion impossible. Due to friction, perpetual motion was "beyond the utmost effects mechanical powers can produce."[22] In 1776, the Paris Academy of Sciences declared that it would no longer consider proposals for perpetual motion, awarding the Academy Prize instead to the topic of friction; less than fifty years later, the engineer Carnot's 1824 *Reflections* on the loss of the horsepower of 1810s engines turns into the founding text of thermodynamics. As Carnot observes, perpetual motion is the state of a perfect engine that can never be reached but only approached; engine design doesn't deny consciousness of loss but rather forcefully struggles against loss for a passing time.[23] Engineering renounces the transcendence of Newton's Prime Mover. No longer made in the image of power divine, human mechanical powers become the only prime movers. Emptied of triumph, machinery critically internalizes a catastrophist logic of struggling to defer dissipation.

In "Turner Translates Carnot," Serres tropes on the rise of thermodynamics in Romantic aesthetics in the passage from simple machines to the steam engine, from the straight lines of the simple machines of the painter George Garrard's advertising sign for the shipyard warehouse of Samuel Whitbread (1784) to Turner's entry into the boilers of steam engines. For Serres: "From Garrard to Turner, the path is very simple. It is the same path that runs from [Joseph-Louis] Lagrange to Carnot, from simple machines to steam engines, from mechanics to thermodynamics—by way of the Industrial Revolution" (*H*, 56). Garrard's shipyard delineates the perfect world of Lagrange's *Analytical Mechanics* (which extended Newton's rational mechanics) on the brink of its dissolution, the "recapitulation of a perfect world soon to disappear" (*H,* 54). The equipment stands out: flawless timberwork, "ships, hawsers tied to the mooring posts, sails at rest, rigging free and in place," "a world that is drawn, drawable" (*H*, 54–55). The pulleys, slings, winches, ropes, and weights of Gerrard's ship sum up the simple mechanics of Newton's world, a world of lines that heroically triumph over matter: the machinery as orderly as the Newtonian universe, human mechanical power as invariable as the divine power it resembles. A ship of the line—with its hawsers, cranes, and mechanical powers—static, at rest, perfectly in order.

Turner, in Serres's account, "change[s] ships" (*H*, 60): Turner stops painting the wooden ship of the line—the simple machinery of Newton's and Garrard's world—and starts painting steam boats. Garrard's shipyard burns up in fire with Turner, who enters into the boiler of the steam boat, into the fire of the engine cylinder. With Turner's steam boats, the art of drawing explodes into fiery color: "For a moment the engine dissolves into the world that resembles it. . . . He passes from the rationalized real, from the abstract or mathematical real, to the burgeoning real that radiates from the furnace where edges collapse" (*H*, 58, 60). Turner enters into incandescence "without theoretical detours," by using some of the same materials in his painting—metals, oils, and resins—that engineers did in the engine (*H*, 62). Freed from the statics of Newton's world, engineering and Romantic painting explode into fiery motion. "Matter and color," Serres reflects, "triumph over line, geometry, and form. . . . Turner sees the world in terms of water and fire, as Gerrard saw it in terms of figures and motion" (*H*, 57). Yet figures in motion don't, as Serres contends, go away but rather are materialized by the painter's and engineer's lines, renouncing any Newtonian claim to formal transcendence, their straightness and regularity abraded from the inside out by thermomechanical friction. Turner's lines are "the height of disorder": the foundry's roof is askew; its equipment unevenly squared; the plumb line has "melted in front of the furnace" (*H*, 60–61). Even the engine is made of "imperfectly machined parts."[24] No less striking are the implications for Romantic aesthetics: Turner translates the rise of thermodynamics into painting not by reading Carnot but by his own mechanical power: through Romantic painting as vehicle for the thermodynamics of figures in motion with the fire engine. No more mechanical powers made in the image of power divine. No more formal transcendence, only the material immanence of thermomechanical force.

In spite of the radiance of Serres's vision, his reading of Romantic painter Turner's fire engines that marks the transition between Newtonian mechanics and engineering from *An Iron Foundry* (1797) to *Rain, Steam, and Speed-The Great Western Railway* (1844) forces us to reckon with the same thermodynamic world of de Man's figure of technology burning history, particularly in an age of anthropogenic climate change often dated to Watt's 1784 steam engine. The new thermodynamic world that emerges out of the engine gives rise to the material condition of the Anthropocene. As a neo-catastrophist concept, the Anthropocene confronts the material relation between the dissipation of human mechanical power—machinery—and thermodynamic and energy systems.[25] One chapter in Anthropocene history is the emergence of the thermodynamic logic of machinery over the Romantic era, in which the combustion of the perfect world of Newton and Garrard in the fire of the engine cylinder forces us to reckon with the rude truth that thermodynamic logic emerges not as an external critique of engineering but from it: the power of machinery that burns down the Newtonian universe.

II. BYRON'S ENGINEERING POETICS

If Serres's passing sketch focuses on the sea change in visual representation between Turner and Carnot, how might Romantic poetry take part in the rise of thermodynamics? The same path that runs from Newton to Carnot, from Garrard to Turner, runs from Alexander Pope to Byron, by way of the combustion of the engine. A sense of constant, perpetual motion—or of unstoppable strength or force—heroically struggling to overcome opposing forces is often taken to be the heat signature of Byron's poetics.[26] If Romantic criticism has long recognized Byron's metaphors taken from mechanics, it has at once obscured its importance in the rise of thermodynamics.[27] I argue that Byron develops a mechanical engineering poetics that is best understood in the context of the end of perpetual motion and dissipation of human mechanical power that marks the transition between Newtonian mechanics and mechanical engineering in the early 19th century. Byron's force—far from anti-empirical—is best understood as thermomechanical force.[28] Byron's new poetic machinery struggles with the production and exhaustion of energy that marks the rise of thermodynamics over the 1810s-20s. Much like Turner and Carnot, Byron's poetic machinery burns through the temptations of permanence of the divinely ordered universe of Newton and Pope for the thermodynamic universe of energy and its perpetual loss that emerges with the engine.

Byron's engineering poetics stretch over his entire poetic career. As early as 1813, Byron explicitly refers to his poetic vocation as "my post as an engineer" with enough poetic force to "have displaced stars enough to overthrow the Newtonian system."[29] Byron's theoretical identification of his poetic vocation with the emerging profession of engineering applies the power of his poetic machinery to displace the static Newtonian universe precisely as engineers were in the 1810s-20s. Byron's engineering poetics shares the core features of engineers' definitions of machinery: machines struggled to "balance or overcome another power or obstacle" that threatened to catastrophically dissipate it, whether friction or the transcendental principles of Newtonian mechanics (*TM*, 2:1). Far from anti-empirical or aristocratic, Byron's engineering poetics critically aligns his poetic vocation with his political sympathies for working mechanics—and the human totality—that develops over his poetic career, from his defense of working mechanics in Parliament to his 1824 death in combat fighting alongside a group of engineers struggling for human emancipation. If the critical power of Byron's engineering poetics is impersonally material as thermomechanical force, it at once aligns with the totality of human mechanical power on a historical materialist scale.

If Byron's engineering poetics span his entire poetic career, it develops most fully with his new poetic machinery in *Don Juan* in the context of the rise of thermodynamics over the late 1810s and early 1820s between Newtonian mechanics and engineering. We can already glimpse the core features of Byron's engineering poetics in the Pope Controversy that flared up in the early days of *Don Juan*.[30] A ship of the line (this time Pope's, not Gerrard's) became the flash point of the dispute on the role of mechanical artifice in poetry. William Bowles had argued for a naturalistic poetics based in "invariable principles" of nature.[31] For Bowles, the natural forces of the wind and the waves are poetic, not the ship (for "the ship is all art").[32] The machinery of the ship is too rude to be poetic, mechanical powers made of vulgar materials: the sail, stripped down to its rude materiality, is nothing more than "coarse canvas," blue bunting," and "three tall polls."[33] Byron defends mechanical artifice, articulating the core logic of his engineering poetics. Painting a Turneresque picture, Byron reenvisions the simple machinery of Pope's and Newton's world with a poet-engineer's sensibility to the new thermodynamic logic of machinery:

> B[owles] asserts that [the] Ship of the Line derives all its poetry not from art, but from Nature. . . . Take away the waves, the winds, the sun, etc. etc., etc., one will become a stripe of blue bunting; and the other a piece of coarse canvas on three tall poles. . . . But the 'poetry of the ship' does not depend on the 'waves,' etc.; on the contrary, the 'Ship of the Line' confers its own poetry upon the waters, and heightens theirs. . . . But what seemed the most poetical of all at the moment, were the numbers (about two hundred) of Greek and Turkish craft, which were obliged to 'cut and run' before the wind, from their unsafe anchorage. . . . The sight of these little scudding vessels, darting over the foam in the twilight . . . their reduction to fluttering specks in the distance . . . their littleness, as contending with the giant element; their aspect and their motion, all struck me as something far more poetical than the mere broad, brawling, shipless sea, and the sullen winds, could possibly have been without them.[34]

For Byron (as for Gerrard or Turner), the equipment or machinery is what stands out: the ship "conveys its own poetry upon the waters."

Most poetic, Byron counters, turning Bowles's terms against him, are precisely its mechanical powers that Bowles considers too rude to be poetic, the "admirable application of the terms" of his "art": the "blue bunting," "coarse canvas," "three tall polls." Byron deconstructs Bowles's naturalistic poetics by dismantling the premise that poetry can ever be natural: "Nature will make no great artist of any kind, least of all a poet . . . the poet is the most artificial, perhaps of all artists."[35] Poetic artifice is irreducibly mechanical: "art" for Byron is the application of human labor power to make something that would not otherwise exist in nature. What's striking is the base materiality of "art" for Byron, who takes the mechanical powers of the ship—the "coarse canvas" of the sail—as most poetic. Art or machinery (materially equivalent for Byron, who refers to anything built by human mechanical power as art) doesn't exist outside of materiality but is immanent to the motion of "matter," which is "always changing."[36] The sail derives its mechanical power from the wind and waves. In fact, without the ocean, "there would be no ship at all."[37] Mechanical powers are not static or fixed but finite concessionaries of larger forces. "[M]ost poetical of all" is "their aspect and their motion in contending with the giant element," struggling to defer material dissipation: "far more poetic than the mere broad, brawling, shipless sea could possibly have been without them": without the human presence. For Byron, art has no transcendent outside or Newtonian exteriority to materiality, no static or fixed line, just material immanence, pure finitude. All of this is Byron reading the world of Pope or Newton through the eyes of a Turner or Carnot.

Byron articulates the core logic of his engineering poetics in relation to the mechanical power of machinery that engineers develop over the 1810s–20s, defined by machinery struggling against the catastrophic dissipation of human mechanical power by larger physical forces.[38] Byron's own experience as a sailor, in which he came into contact with many working mechanics and sailor-engineers, no doubt had an impact.[39] Byron defines the relation between the poet's mechanical power and an unruly nature by struggle: "contend": "to struggle," to "strive in opposition; to engage in conflict or fight."[40] The poet's and the engineer's force is not natural but rather artificial, like the sail struggling with the forces that threaten to dissipate it. As one engineer described sail-cloth as a mechanical power in 1816: a "canvas" "made of sail-cloth" must have "very considerable strength" to withstand the counterforce of both "air and water" (*TM*, 2:316). Any machinery of the ship must be made in "point of strength" to bear the "strain on each part" by the counterforce of the wind and water that wear against it, threatening to dissipate its form and force (*TM*, 2:317). Emptied of any triumph, the logic of machinery diminishes human power, reduced to "littleness" contending with the "giant" element. Yet even in diminishing human mechanical power, Byron locks it in the crosshairs, defining his engineering poetics with the terms engineers used to defined machines: most poetic is the "admirable application of the terms" of his "art": "a good workman"—whether a poet or engineer—"will not find fault with his tools."[41] As one engineer wrote in 1815, "Machines are nothing more" than "tools interposed between the workman" and the human struggle to "counterbalance or overcome another power or obstacle" such as friction and catastrophic wear by the elements that threatened to destroy it (*TM*, 2:1).

At the heart of the Pope Controversy is Byron's articulation of a dynamic view of the material universe that fuels his engineering poetics precisely to the extent that it is anti-philosophical or materialist in character.[42] Like engineers at the time, Byron turns energy and its dissipation by the practical application of mechanical power against the static mechanics of Newton and Pope's world to break down any transcendental principles that triumph over matter. Byron concludes, "I now come to Bowles's 'invariable principles of poetry'. . . . I do hate that word *invariable*. What is there of *human* things, be it in poetry . . . matter, life, or death, which is '*invariable*? Of course, I put things divine out of the question."[43] Nothing human is invariable—like the mechanical power of the sail—because human things are material, cut off from divine power. Freed from transcendental determination, matter for Byron is not static but dynamic: "always changing" with the frictive "jar of atoms," like the sail at once energized and worn away by the wind and water.[44] Just as Byron does, engineers in the 1810s took the coarse cloth of the sail to exemplify "Variable Motion" (*TM*, 1:181).[45] No more powers that triumph over matter, only human mechanical powers contending with unruly physical forces.[46] For Byron, nothing but dynamic motion persists in a universe in which the only constant is the unceasing mutual interchange of figures. Ending the Pope Controversy with the remark that "a good workman will not find fault with his tools" (and workmen in the 1810s are working mechanics or engineers), Byron burns through any notion that poetic making can ever escape from its rude mechanical powers.[47]

What matters about the Pope Controversy is how Byron's engineering poetics emerges in opposition not only to naturalist poetics—from Bowles to William Wordsworth—but also the pre-industrial, pre-thermodynamic logic of machinery of Pope's or Garrard's world, all too static in its triumph over matter.[48] Poetic machinery for Pope imitated divine powers in moving the poem forward, an epic trope. The poet's machinery thus resembled power divine: transcendental forces exterior to materiality like Newton's Prime Mover. If it exerted its force over late 18th-century poetry, the machinery of Pope's and Newton's world was on the brink of its dissipation by the time of the Pope Controversy. The 1819 *Cyclopædia* article on "Machinery" in Poetry (next to the entry by an engineer) defined machinery as "when a poet brings" in some "divine power" to "solve some difficulty out of the reach of human power" (*RC*, "machinery"). The epic poet "does nothing but by machines": "there must be machines" in "every part" as the "gods are both good, bad, or indifferent" (*RC*, "machinery"). In 1819, the same year as the "Machinery" article, Byron writes to Murray with his plans for *Don Juan*'s new poetic machinery: "You have so many divine poems, is it nothing to have written a human one? Without any of your worn-out machinery"; rather, "human" mechanical powers, "good or bad, must serve for the machinery" of "*Don Juan*."[49] Ruling out "divine poems," any machinery of Newton or Pope's world, Byron turns to "human" things: to the variable force of machinery itself. James Chandler is right: Byron saves Pope for the poetry of the past, not for Romantic poetry.[50] "Excuse this engineering slang," Byron remarks, measuring his poetic force by the "metaphor taken from the forty-horse-power of a steam engine," the first use of the engineer's measure of mechanical power in the *OED* outside an engineering treatise.[51] Much like Turner, Byron changes machinery. Rhyme, the rude "tool that good workmen never quarrel with" in canto 1—retooling his Pope Controversy line—soon turns into the "steam-boat which keeps verses moving."[52] Byron's poetic machinery cannot be reduced to Pope's, which he radically rejects in a poem of only "materials."[53] Rather, it emerges out of the thermodynamic logic of machinery itself: early nineteenth-century engineering.

By working with their tools, engineers over the early 19th century discovered the irreversible loss of force that turns into entropy. Engineers fit together machine parts called couplings to maximize the engine's power by reducing the force lost by friction. To an extent, machine parts had to be tightly fit together—force-paired or pair-closed —by screw-nut couplings to reduce friction. Yet fitting machine parts together too tightly in fact increased friction, as their figures would wear against one another. Engineers thus lubricated machine parts to fit them together less tightly, oiling the nuts of the female screw coupling the engine together to reduce the great friction in the male screw slipping inside it.[54] Particularly critical was reducing the force lost by the engine coupler, the engine's central linkage that translated the piston's rise and fall into the torque that powered machinery. As Müller-Sievers notes, "engineers used Schillerian terms like *play* and *tolerance* to mark this contradiction, and in German the sealing gasket that was supposed to fill and leave open this space . . . was even bestowed the sacred term for poetry."[55] Against Bowles, the logic of machinery demanded keeping a space open for free motion that was called poetic. Lubricating machine parts, one engineer reflected, let them "play up and down without rubbing on the sides, which would quickly wear it out" (*TM*, 2:317). Machinery should be "supplied with oil" to prevent "obstructing its free play" (*TM*, 2:299) so that it had "sufficient freedom of motion" (*RC*, "steam-engine") to "play freely" without "sliding to and fro" (*TM*, 2:349). Reducing the friction from the slippage of the paired couplings of parts demanded freedom of motion to maximize the power of the engine.

Engineers developed a thermodynamic aesthetics of freedom out of the logic of machinery. Rough, frictive motion and the loss of force was aesthetic displeasure, like the screw abrading the nut. Novalis, a mining engineer, called frictive motion displeasure.[56] "Pleasure," as engineers termed it, corresponded to dynamic, "free" motion unimpeded by rough friction: fluid, lubricated machine parts could "play freely" and "varied at [the engineer's] pleasure" just as smooth, unimpeded motion was pleasurable (*TM*, 2:349, 2:351). Pleasure was thus the feeling of mechanical power increasing or friction, or resistance to motion overcome. With the masculine and feminine endings of machine parts, the physiological correlates were part of material experience: "pleasures unredeemed by transcendence that debase a human essence."[57] Anti-transcendental, aesthetic freedom lay not in the Kantian free play of the faculties but in the dynamic motion of thermomechanical force relatively unimpeded by friction and freed from any static fit of parts too tight for free motion, like Byron's "fire / And motion of the soul" that burns through every "fitting medium of desire" like the motive power of his new poetic machinery.[58]

Byron's poetic machinery turns precisely this free, dynamic motion of thermomechanical force into the engine of poetry. As opposed to machinery in general, thermodynamics takes a distinctly semiotic form with poetic language in the form of signifying force and its dissipation. In translating how Byron's engineering poetics turn "extreme suspicion"—critical consciousness—and "playful mischief"—semiotic dissipation—into the engine of poetry, Walter Scott compares

Byron's "imaginative force" to the thermodynamics of machinery.[59] As Scott observes, Byron's poetic "force" is fueled by the engineering principle that "the wheels of a machine to play rapidly must not fit with the utmost exactness else the attrition diminishes the impetus."[60] "Minimizing the attrition"—the friction produced by the parts fitting too tightly—by "playful" yet "suspicious" ironic labilities of language—frees up Byron's "imaginative power" so that it can "play more rapidly."[61] Byron's playful yet suspicious labilities of language are the lubricants that free up the dynamic force of his poetics. By fitting together poetic language with room for semiotic dissipation, Byron frees the dynamic yet dissipate power of poetic language. Like the engineer's suspicion of fixed principles, the "extreme suspicion" of Byron's imaginative power is anti-transcendental and materialist, turning against the statics of Newton's world.[62] Scott makes no mention of prosody: for Scott, Byron's machinery is more fundamentally semiotic than prosodic, extending to all poetic language rather than limited to any verse form like *ottava rima*. If Scott is ultimately right, he overlooks how Byron articulates his engineering poetics in relation to rhyme. Byron uses rhyme metonymically for his machinery as the form of poetic making self-conscious of its mechanical power that makes use of rhyme as a tool but is not limited to it.

In retooling Romantic poetry, Byron reengineers rhyme's mechanical reputation. "Rhyme" turns into the "steam-boat" that "keeps verses moving" coupled into "faithful pairs," the force-paired couplings of lines that defer dissipation by perpetuating the power of poetic language.[63] "Couplet" itself etymologically derives from two pieces of iron riveted together by screws, the fundamental mechanical couplings that maximized the engine's power.[64] In another engineering metaphor, Byron reflects on how the "engineer's" machinery dissipates "for the same cause which makes a verse want feet," the "haste, or waste" by which it is fit together.[65] Like attrition, "waste" is engineering slang for frictive dissipation. Yet rather than over-identify his poetic machinery with prosody, Byron uses rhyme metonymically to reengineer the more fundamental semiotic dynamic of rhyme's mechanical reputation critiqued by proponents of the rational freedoms of blank verse for semiotically decoupling sound from sense—or, more to the point, language's material motion from its rational content.[66] Rather than force rhyme to reason—as rhyme's defenders often did—Byron critically turns the motion of poetic language against its rational content. For Byron, the engine of rhyme "keeps verses moving / 'Gainst reason."[67] If for Chandler, Byron's materialist tendency is undone by the "ironic labilities" of his language, my claim is that such labilities are the most radical expression of it. [68] The labilities of Byron's poetic language—much as Scott saw—are the lubricants that fuel the dynamic motion of his poetic machinery that can't be decoupled from its frictive dissipation:

> Of faithful pairs (I needs must rhyme with dove,
> That good old steam-boat which keeps verses moving
> 'Gainst reason—Reason ne'er was hand-and-glove
> With rhyme, but always leant less to improving
> The sound than sense), beside all these pretences
> To love, there are those things which words name senses
> Those movements, those improvements in our bodies.[69]

How exactly does Byron's machinery "keep verses moving against reason"? The "senses" of the mechanical vehicularity of poetic language—its mechanical power as a finite mechanism to defer dissipation—are at stake. On one level, language defers dissipation to the extent of its communicative rationality: the extent to which its motion is a vehicle of "sense" or rational content, and entropic to the extent that its fails to transport its tenor to a definite referent. Just as friction is produced by the slippage of figures abrading one another in motion, so for Byron friction is semiotic slippage that ironically dissipates the rationality of poetic language. Yet in a ruder sense, for Byron, poetry's power to "keeping verses moving" defers dissipation to the extent that it perpetuates the motion of poetic language, keeping language moving line by material line. "Dove"—which the engine of the couplet "needs must rhyme" with "love"—is an empty signifier with no meaning other than to keep verses moving. Burning through the communicative rationality of poetic language, the engine of rhyme forces "dove" to pair with "glove" and "love" purely to perpetuate the motion of poetry by line. Combusting language's referential content, Byron's verse turns reference into the raw fuel for perpetuating the motion of language.[70] Not only does the engine of rhyme "lean less to improving" the sound than the "sense" but its mechanical force ironically dissipates language's rational content, unfixing the motion of poetic tropes from any pretense to "things which words name." The sense of "sense" itself is subjected to a series of frictive slippages in the lines by the "movements" in "our bodies" that dissipate its rational content.[71] The engine of rhyme thermomechanically abrades the sense of reason itself, moving the referent of "sense"—initially "reason"—from "senses" to "pretences" to "improvement" and "movement." The referent of sense slips from "reason" to "movements in our bodies," which in turn slips into the lubricious movements of the screwlike "loving" of the "pairs" of force-paired couplets. The force-paired screws of the masculine and feminine endings of the engine of rhyme—coupling together "dove" and "love" and "moving" and "improving"—at once perpetuate the motion of poetic language and frictively dissipates it. Byron takes us into the engine cylinder of verse, into the mechanical force of tropes behind "all these pretenses" to "things which words name." Ironically, perpetuating the rude mechanical motion of poetic language frees up the motion of poetry from any rational mechanics of fixed or definite reference. At stake is a thermodynamic logic of poetry and machinery in all its material impermanence, autonomous from any transcendental principle outside of matter itself.

III. OUT OF STEAM

What critical value, however, can the thermodynamic logic of machinery still have in a time of anthropogenic climate change dated to the engine? It has recently become popular to assert that thermodynamics fueled fossil capitalism's progressive visions of limitless steam power.[72] Yet this claim proves unsustainable. Over the 1810s-20s, engineers developed a historical consciousness out of the engine that radically diminished any ideal of human progress. With friction, any progress fueled by the engine dissipated with it. Far from triumphalist, machinery became defined by the struggle against the catastrophic dissipation of energy. As it leads to a historical consciousness of the dissipation of energy systems, rendering human power a finite concessionary of the planet's resources, thermodynamics is increasingly recognized as foundational for ecological thought in the Anthropocene. As Allen Macduffie observes, "Despite its commitments . . . to industrial development, thermodynamic writing contained within it the seeds of an ecologically conscious discourse" about human energy practices.[73] Macduffie's remarks typify the critical tendency to recognize both the critical value of thermodynamics and the tension with its emergence out of steam. To recover the critical value of the thermodynamic logic of machinery for Anthropocene thought, we must grasp how it at once emerges from the steam engine but is not reducible to it in order to negotiate the particular and universal forms of dissipation on a planetary scale. Universal dissipation has doubled in Anthropocene history, planetary climate catastrophe caused by the dissipation of the steam engine supervening upon the heat death of the sun.[74] Paul Crutzen has recently argued that geoengineering may be necessary to fight planetary scale dissipation, as merely renouncing it may no longer be sufficient.[75] Yet one need not accept geoengineering to admit that some form of machinery—such as renewable energy technology—may be necessary to get out of steam.[76] Byron's engineering poetics prefigures such a mode of Anthropocene response to the dissipation of energy systems: applying the thermodynamics of machinery to fight against dissipation on a terrestrial scale.

As a "prophet of ecocide," Byron has often been taken to prefigure a pessimistic form of ecological response to universal dissipation.[77] Yet the critical strength of Byron's poetics—and the thermodynamic logic of machinery from the time of Romanticism to the present—ultimately lies not in renunciation but in militant struggle. If Byron's view of history is rightly taken to be catastrophist, this is only half of his historical consciousness that emerges out of machinery:

> When Newton saw an apple fall, he found
> In that slight startle from his contemplation—
> 'Tis said (for I'll not answer above ground)
> For any sage's creed or calculation)—
> A mode of proving that the earth turned round
> In a most natural whirl called 'Gravitation,'
> And this is the sole mortal who could grapple,
> Since Adam, with a fall, or with an apple.
>
> Man fell with apples, and with apples rose,
> If this be true; for we must deem the mode
> In which Sir Isaac Newton could disclose
> Through the then unpaved stars the turnpike road,
> A thing to counterbalance human woes;
> For ever since immortal man hath glowed
> With all kinds of mechanics, and full soon
> Steam-engines will conduct him to the Moon.
>
> And wherefore this exordium?—Why just now,
> In taking up this paltry sheet of paper,
> My bosom underwent a glorious glow,
> And my internal Spirit cut a caper
> And though so much inferior, as I know,
> To those who, by the dint of glass and vapour,
> Discover stars, and sail in the wind's eye,
> I wish to do as much by Poesy.[78]

Canto 10 of *Don Juan* represents Byron's most explicit reflection on the rise of the steam engine.[79] The lines translate the rise of mechanical power from Newton to steam engines, from simple mechanics to engineering into the planetary scale power that has come to define the Anthropocene. In fact, Byron composed canto 10 shortly after he received a letter from an engineer who requested his support in developing steam engines capable of air travel. Byron responded enthusiastically. Thomas Medwin was skeptical of the engineer's proposal. But Byron counters Medwin's skepticism: "I suppose we shall soon travel by air vessels . . . and at length find our way to the moon, in spite of the want of atmosphere. . . . There is not so much folly as you might suppose, and a vast deal of poetry, in the idea."[80] Canto 10, as Medwin already saw in 1824, is Byron's attempt to realize the poetry in the engineer's idea through the force of his engineering poetics, here "to do as much by Poesy" as steam-engines to the moon, rivaling the engine's planetary scale mechanical power that has come to define the Anthropocene. Byron's measure of poetry's and the engine's power cuts two ways: if on the one hand, the engine fuels the motion of the poem, and the energy of the poetic language in canto 10—just as Byron finds "a vast deal of poetry" in the rise of the engine's power on a terrestrial scale that persists despite Medwin's skepticism—Byron's poetic machinery at once frictively abrades the engine's power and any progressive view of history it fuels, though it does so without exhausting that power completely. On one level, the motion of Byron's poetic machinery might be called progressivist insofar as it fights to defer dissipation or "counterbalance human woes" by keeping verses moving with every new canto of *Don Juan*. Yet any such progressive energy is at once diminished by the semiotic frictions that can't be decoupled from the motion of the poem, frictions internal to the combustible energy that at once fuels and dissipates the signifying power of poetic language. The very excessive, overheated energy of the language "full soon / Steam-engines will conduct him to the Moon," for instance, at once fuels and frictively abrades its own power to signify that progressive trajectory. When Byron refuses to measure how far the engine will rise while "above ground," his poetic language also reminds the reader of coal's origins below ground and of the planetary limits of energy. Byron prefigures a catastrophic fall back to the planet's surface once that finite energy source runs out of steam.

The effect of the thermodynamic engine of the poem itself is to reduce human power to a catastrophic struggle to "counterbalance human woes" on a planetary scale through machinery, poetic or otherwise, a diminished heroic struggle made even more explicit in Byron's letter to the engineer fueling canto 10. Byron continues: "Might not the fables of Prometheus, and his stealing the fire . . . be but traditions of steam and its machinery? Who knows whether, when a comet shall approach this globe to destroy it, as it has often been destroyed, men" might not stop it "by means of steam" or another engine?[81] Contending with the giant element, Byron's machinery fights to defer global catastrophe. On a planetary scale in which human mechanical power is reduced to a fluttering speck in the distance of universal dissipation, the struggle is at once diminished and rendered more critical. That other species went extinct despite their advanced machinery frictively abrades any hope in human technological progress. Yet even in diminishing human power, Byron sees "a vast deal of poetry" in its struggle. Faced with global catastrophe, Byron keeps fighting against dissipation on a planetary scale. Battling alongside engineers in his last days in 1823–24, participating in the cause for Greek liberation, Byron directly applies his poetic "post as an engineer" to a global struggle, personally ordering the latest armored steam-boats to be directly applied to the fight. Befriending the six engineers in his battalion, "fine rough fellows," Byron praises their cutting edge "factory" as a "model" of applying machinery "only for the public benefit."[82] While the struggle in this case is very different from climate change, the same logic of machinery fuels Byron's engineering poetics in fighting to avert catastrophic dissipation on a planetary scale.

Byron would likely be the first to appreciate that the globe is now all the more likely to destroyed than saved by "steam and its machinery," and that other machinery might at once combat such a planetary scale catastrophe. If Byron could not yet fully anticipate the particular planetary damage of carbon emissions—an additional friction present in reading Byron in a time of anthropogenic climate change—his engineering poetics may now provide critical tools for combating it, although they would have to be more explicitly turned against rather than fueled by steam to be useful today. Andreas Malm has shown the critical necessity of the thermodynamic logic of machinery for fighting catastrophic dissipation on the planetary scale that Byron envisions. As Malm observes, "Progress today really does mean simply the prevention and avoidance of total catastrophe" in "opposition to the forces of this storm."[83] Rather than rejecting mechanical power, any chance of avoiding catastrophe will involve repurposing machinery to fight against catastrophic dissipation on a planetary scale. Advocating a path to eco-militancy, Malm insists that human mechanical powers must "commit to the most militant and unwavering opposition" to the "forces of this storm" to "make this little planet habitable": critically, through negative emissions technologies and renewable energy technologies.[84]

As Malm shows, such mechanical powers are now aligned with global class struggle, and the interests of the planet itself.

If the Anthropocene is not only a techno-scientific problem that, as Crutzen argues, requires scientists and engineers to fight for "environmentally sustainable management" but also, as many now recognize, irreducibly figurative and aesthetic, poetry might play a critical role in forming our historical consciousness of the totality and dissipation of energy systems and mobilizing the affective energy and critical friction to effectively combat planetary catastrophe.[85] Now more than ever, we need Byron's critical diminishment of human power combined with his militant commitment to historical-material struggle, to at once figure out the frictions in proposed techno-fixes without rejecting the real tools at our disposal. Like Ernst Bloch's militant optimism, Byron's engineering poetics couples a frictive pessimism of the intellect to an optimism—or heightened energy—of the will. Emptied of any triumph, poetry might retain its power as a form capable of at once thinking totality and dissipation and combating it through militant struggle. How successfully poetry can contribute to this struggle today is an open question, especially at a time when poetry itself can seem to have run out a steam as a literary form, a notion challenged by the recent flourishing of popular Anthropocene poetry committed to such a militant struggle. One recent poetry and short story collection, *Sunvault*, engineers solar-powered forms of poetry with the explicit goal of combating planetary scale dissipation in the wake of climate change. The planned companion volume *Almanac for the Anthropocene* will relate *Sunvault*'s poetry to engineering blueprints for solar-power technologies to militate against "capitalism and climate disaster."[86] Poetry today might at once renew its own energies as a literary form and fight against climate change in part by retooling and reengineering sustainable, renewable forms of the thermodynamic aesthetics that have fueled it since the Romantic era.

If it is necessary to ascribe a virtue to the thermodynamic logic of machinery that arises over the time of Romanticism, it is how it prefigures a renewed historical materialism that lies in the critical application of science and technology rather than its rejection, one equipped to struggle eco-militantly against the planetary catastrophe of thermodynamic systems to keep this planet habitable.[87] For Byron, nature is not only a sheltering sky or vital presence but an unruly force that we must struggle with, whether in contending with the giant element, whatever comet approaches the globe to destroy us, or now, planetary scale climate catastrophe. Any chance of averting catastrophic dissipation will have to be a struggle fought by mere mortals. Byron's engineering poetics leaves us with no guarantees outside of planetary dissipation, and the determination to struggle against it. A renewed historical materialism that Byron prefigures might take this eco-militant struggle as its ground zero to oppose the forces that now threaten the planet. Only then can we hope to "counterbalance human woes," lest the end of history come with our own "want of atmosphere," in an ironic inversion of Byron's engines to the moon, burnt away without material residue. Otherwise, the end of our mechanical powers will be ruder still. Such an eco-militant engineering poetics now demands to be considered not only because its thermodynamic aesthetics has quietly shaped Anthropocene history since the time of Romanticism and continues to do so, but because it may very well provide critical tools for reconsidering what work poetry can do today to combat our current climate catastrophe.

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NOTES

[1] Paul de Man, "The Temptation of Permanence," in *Critical Writings, 1953–1978*, ed. Lindsay Waters (Minneapolis: Univ. of Minnesota Press, 1989), 30.

[2] de Man, 31.

[3] See Paul Crutzen, "Geology of Mankind," *Nature* 415.23 (2012): 23. While the dating (and term) Anthropocene are hotly debated, James Watt's 1784 steam engine design has substantial traction.

[4] Mechanical power in Romantic era mechanical engineering and culture referred at once to the elementary parts of machines (such as the nut and screw), machines or engines themselves, and the human powers that machines produce.

[5] Byron to John Murray, 29 November 1813 in *Letters and Journals* 12 vol., ed. Leslie Marchand (Cambridge: Harvard Univ. Press, 1973), 3:182.

[6] For classic studies of the rise of thermodynamics, see D. S. L. Cardwell, *From Watt to Clausius: The Rise of Thermodynamics in the Early Industrial Age* (Ithaca: Cornell Univ. Press, 1971); and Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: Univ. of Chicago Press, 1998). Ted Underwood's *Work of the Sun: Literature, Science and Political Economy, 1760–1860* (London: Palgrave Macmillan, 2005) is the single major Romantic study to date, and, as entropy occurs only once in a footnote, more on energy than thermodynamics. For major studies of thermodynamics in 19th-century literature, see Allen Macduffie, *Victorian Literature, Energy, and the Ecological Imagination* (Cambridge: Cambridge Univ. Press, 2014); and Barri J. Gold, *ThermoPoetics: Energy in Victorian Literature and Science* (Cambridge: MIT Press, 2010).

[7] Michel Serres, *Hermes: Literature, Science, Philosophy*, ed. J. Harari and D. Bell (Baltimore: Johns Hopkins Univ. Press, 1982), 71. Hereafter abbreviated *H* and cited parenthetically by page number.

[8] "Friction," in *Rees's Cyclopædia or Universal Dictionary of the Arts, Science and Literature*, 39 vol., (London: 1819): 15:369, hereafter abbreviated to *RC* and cited

parenthetically by entry, volume, and page number. Mechanical engineers wrote the entries on machinery. Not to be conflated with Chambers's *Cyclopædia.* For more on Rees's *Cyclopædia,* see Celina Fox, *The Arts of Industry in the Age of Enlightenment* (New Haven: Yale Univ. Press, 2009).

[9] See Helmut Müller-Sievers, *The Cylinder: Kinematics of the Nineteenth Century* (Berkeley: Univ. of California Press, 2013); and Simon Schaffer, "Machine Philosophy: Demonstration Devices in Georgian Mechanics," *Osiris* 9 (1994): 157–82.

[10] Müller-Sievers, *The Cylinder,* 173n.

[11] Müller-Sievers, *The Cylinder*, 22.

[12] See R. A. Buchanan, *The Engineers: A History of The Engineering Profession in Britain 1750–1914* (London: Kingsley, 1989).

[13] Olinthus Gregory, *A Treatise of Mechanics,* 3 vol. (London: 1815): 2:1. Hereafter abbreviated TM and cited parenthetically by volume and page number.

[14] Isaac Newton, "Preface to the Principia," in *Newton*, ed. Bernard Cohen and R. Westfall (Norton, 1995), 225.

[15] The Mechanics' Institute was a workers' institution founded by mechanics with radical political ambitions. See Kyoko Takanashi, "The Romantic Origins of the Mechanics' Institute," (Conference Paper, North American Society for the Study of Romanticism, Providence, RI, June 2018).

[16] Robert Stuart, *A Descriptive History of the Steam Engine* (London, 1824), v.

[17] Stuart, *A Descriptive History of the Steam Engine*, v.

[18] Stuart, *A Descriptive History of the Steam Engine*, v-vi.

[19] Stuart, *A Descriptive History of the Steam Engine, v.*

[20] See Schaffer, "Machine Philosophy," 172–78.

[21] See Stuart, *Descriptive History of the Steam Engine*, 113 for these lubricants.

[22] The Academy's proclamation is in *Histoire de l'Académie Royale des Sciences* (1775), Paris, 1778, 61–66; Thomas Reid to Richard Price, 1772, in *Correspondence of Richard Price*, ed. W. Peach (Durham: Duke Univ. Press, 1983), 1:154.

[23] See Sadi Carnot, *Réflexions sur la puissance motrice du feu et sur les machines propres à developer cette puissance* (Paris, 1824).

[24] To repurpose Helmut Muller-Sievers's term for engine design in *The Cylinder*, 60.

[25] For this relation as definitive of the Anthropocene, as Tobias Menely and Jesse Oak Taylor remark, see their introduction to *Anthropocene Reading: Literary History in Geologic Times*, ed. Tobias Menely and Jesse Oak Taylor (University Park: Penn State Univ. Press, 2017), 12. For the Anthropocene as a neo-catastrophist concept, see Jeremy Davies, *The Birth of the Anthropocene* (Berkeley: Univ. of California Press, 2018).

[26] On the critical trope of Byron's strength or force, see Jerome Christensen, "Romantic Strength v. Empirical Force," in *Lord Byron's Strength: Romantic Writing and Commercial Society* (Baltimore: Johns Hopkins Univ. Press, 1993), 4; Jerome McGann, "Byron and the Force of Circumstance," *Don Juan in Context* (Chicago: Univ. of Chicago Press, 1976), 1–10; and Emily Rohrbach, *Modernity's Mist: Romanticism and the Poetics of Anticipation* (New York: Fordham Univ. Press, 2015), 134–61. On Byron's force as a heroic, agonistic struggle, see Susan Wolfson, "Byron's Heroic Form" in *Formal Charges: The Shaping of Poetry in British Romanticism*, 133–63; McGann, *Don Juan in Context*, 11–50; and Gerard Cohen-Vrignaud, "Rhyme's Crimes," *ELH* 82.3 (2015): 987–1012.

[27] See James Chandler, "Byron's Causes: The Moral Mechanics of *Don Juan*," in *England in 1819: The Politics of Literary Culture and the Case of Romantic Historicism* (Chicago: Univ. of Chicago Press, 1999), in which Chandler notes "Byron's emphatic

resort to metaphors drawn from mechanics" (358); McGann, "Byron and the Force of Circumstance," 1–10; Christensen, "The Circumstantial Gravity of *Don Juan*," in *Lord Byron's Strength*, 214–57. By "mechanics," Chandler, McGann, and Christensen refer to Newtonian mechanics rather than engineering on the level of generality at which Newton's and Hume's "mechanics" are interchangeable.

[28] My argument runs directly counter to Jerome Christensen's identification of Byron's strength with his "lordship" over against empirical force in "Romantic Strength v. Empirical Force," in *Lord Byron's Strength*, 4.

[29] Byron to John Murray, 29 November, 1813 3:182; 7 December 1813, 3:236.

[30] For more on the historical context of the Pope Controversy, see James Chandler, "The Pope Controversy: Romantic Poetics and the English Canon," *Critical Inquiry* 10 (1984): 481–509.

[31] Byron to Murray, 7 February 1821, in *Lord Byron, The Complete Works,* 13 vol., ed. Peter Cochran (Cambridge: Cambridge Press, 2009), 12:296. Unless otherwise noted, all subsequent references to Byron's letters, "Detached Thoughts," *Don Juan,* and *Childe Harold* refer to this edition and are cited by canto and line number for the poems and by volume and page number for the letters and "Detached Thoughts."

[32] Byron to Murray, 7 February 1821, 12: 303.

[33] Byron to Murray, 7 February 1821, 12: 303.

[34] Byron to Murray, 7 February 1821, 12:297–98. Unless otherwise noted, all subsequent references to Byron's work refer to this edition.

[35] Byron to Murray, 7 February 1821, 12: 301.

[36] Byron, "Detached Thoughts," 12:267.

[37] Byron to Murray, 7 February 1821, 12: 298.

[38] Many of the engineers who developed the steam engine were also sailors. At first, the engine was initially applied for "raising water" from mines and "pumping water from ships." For instance, see Captain Savery, a "sailor-engineer" whom Robert Stuart, like many engineers, includes in his *Descriptive History of the Steam Engine*, 29, 40.

[39] On Byron's maritime experience, see Talissa Ford, *Radical Romantics: Prophets, Pirates, and the Space Beyond Nation* (Edinburgh: Edinburgh Univ. Press, 2016).

[40] *OED*, s.v., "contend, v.," 1, 2a.

[41] Byron to Murray, 7 February 1821, 12:302; "Further Addenda for insertion in the letter to J[ohn] M[urray] Esq., on Bowles's Pope," 1 September 1821, 12:343. "Application" was itself an engineering term. For instance, in a *Treatise of Mechanics*, Gregory writes of "the application" of "practical engineers" (*TM*, 2:233); the "application of the steam-engine" (*TM*, 2:390) for "giving motion" (*TM*, 2:384).

[42] Chandler observes how Byron's poetics are "anti-philosophical, or materialist" in *England in 1819*, 363.

[43] Byron to Murray, 7 February 1821, in *Letters and Journals*, 12:297–302.

[44] Byron, "Detached Thoughts," 12: 267.

[45] See Gregory, "Variable Motion," in *TM*, 1:181. Gregory takes "the wind on the sails" as his primary example of variable motion. ("When a moving body is subjected to the energy of a force which acts on it. . . . in a different manner at each instant, the motion is called in general, variable motion" [*TM*, 1:181]).

[46] Byron, *Don Juan*, 2.1696; *Letters and Journals*, 12:267–68, 12:297–302.

[47] Byron, "Further Addenda for insertion in the letter to J[ohn] M[urray] Esq., on Bowles's Pope," 1 September 1821, 12:343. Engineering treatises in the 1810s–20s are filled with markers of mechanic's slang denoted by the phrase "as the workmen call it," the same term Byron uses. See Gregory, *TM*, 2:53, 2:179, 2:453, 2:461.

[48] If Pope's machinery is largely outside the scope of this essay, the 18th-century epic trope of poetic machinery traces to the *Rape of the Lock* (and back to Aristotle's *deus ex machina*). For this genealogy, see Joseph Drury, *Novel Machines: Technology and Narrative Form in Enlightenment Britain* (Oxford: Oxford Univ. Press, 2017), 27.

[49] Byron to Murray, 6 April 1819, *Medwin's Conversations of Lord Byron*, ed. Ernest J. Lovell (Princeton: Princeton Univ. Press, 2016), 165.

[50] See Chandler, "The Pope Controversy," 505. While he rightly notes that Byron "saves Pope for not for the history of the future but for the history of the past," Chandler only links this to Byron's rejection of Pope's invariable principles of nature rather than to his poetic machinery.

[51] Byron, *Don Juan*, 7.86, 10.265n. See *OED*, s.vv., "horsepower, n."

[52] Byron, *Don Juan*, 9.588.

[53] Byron to Murray, 12 August 1819, *Letters and Journals*, ed. Leslie Marchand, 6: 207.

[54] On friction in male and female screw-nut couplings, see *RC*, "screw"; *RC*, "machinery."

[55] Müller-Sievers, *The Cylinder*, 60.

[56] Bryan Norton, "Novalis's Perpetuum Mobile: Towards a Thermodynamic *Naturphilosophie*," (Conference Paper, North American Society for the Study of Romanticism, Providence, RI, June 2018).

[57] To repurpose Cohen-Vrignaud's apt phrase for Byron's rhyme in "Rhyme's Crimes," 992.

[58] *Childe Harold's Pilgrimage*, 3.371, 3.374. Byron also glosses "my spirits" as the fuel of his "machinery," a felt sense of mechanical power. See Byron to Murray, 6 April 1819, *Medwin's Conversations of Lord Byron*, 165.

[59] Walter Scott, 23 November 1825, *The Journal of Sir Walter Scott*, ed. David Douglas (Edinburgh: Douglas, 1891), 12.

[60] Walter Scott, 23 November 1825, *The Journal of Sir Walter Scott*, 12.

[61] Walter Scott, 23 November 1825, *The Journal of Sir Walter Scott*, 12.

[62] Walter Scott, 23 November 1825, *The Journal of Sir Walter Scott*, 12.

[63] Byron, *Don Juan*, 9.587–88.

[64] See *OED*, s.vv. "couplet, n."

[65] Byron, *Don Juan*, 7.203, 7.209–10.

[66] On rhyme's "mechanical reputation," see Cohen-Vrignaud, "Rhyme's Crimes," 987–1012.

[67] Byron, *Don Juan*, 9.588–89.

[68] For Chandler, despite Byron's "materialist orientation," the "lability of the ironies" of his language ultimately "make it difficult to conduct a materialist analysis of his project." *England in 1819*, 363–65.

[69] Byron, *Don Juan*, 9.587–592.

[70] See *Don Juan,* 14.430, "My Muse despises reference," which Christensen takes as his study's epigraph in *Lord Byron's Strength*, 3.

[71] Susan Wolfson notes how the series of displacements of "sense" in the lines culminating in the "movements" render the "the exact sense of sense allusive," in *Formal Charges,* 141.

[72] See, for instance, Cara New Daggett, *The Birth of Energy: Fossil Fuels, Thermodynamics, and the Politics of Work* (Durham: Duke Univ. Press, 2019).

[73] Macduffie, 14, 82.

[74] To be clear, the CO2 emitted by the steam engine is the particular form of dissipation, entropy the general.

[75] See Paul Crutzen, "Geology of Mankind," 23; geoengineering is hotly debated. For a good critical overview, see Holly Jean Buck, *After Geoengineering: Climate Tragedy, Repair, and Restoration* (New York: Verso, 2019); and Clive Hamilton, *Earthmasters: The Dawn of the Age of Climate Engineering* (New Haven: Yale Univ. Press, 2013).

[76] On the exhaustion of critique in the Anthropocene, see also Bruno Latour, "Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern," *Critical Inquiry* 30.2 (2014): 225–48. If Latour rightly acknowledges the need for new tools, my argument is very different from Latour's and not an endorsement.

[77] Jonathan Bate, "Living with the Weather," *Studies in Romanticism* 35.3 (1996): 437. See also David Higgins, *British Romanticism, Climate Change, and the Anthropocene: Writing Tambora* (London: Palgrave Macmillan, 2017).

[78] Byron, *Don Juan*, 10.1–24. On Byron's catastrophism, see Chandler, *England in 1819*, 381–82; and Noah Heringman, "The Anthropocene Reads Buffon (or, Reading Like Geology)" in *Anthropocene Reading*, 59–77.

[79] Chandler calls the exordium Byron's most explicit reflection on mechanics raised to a "version of history" in *England in 1819*, 366, a phrase he in turn repurposes from Peter Manning, *Byron and His Fictions* (Detroit: Wayne State Univ. Press, 1978), 214–16.

[80] Byron, in *Medwin's Conversations of Lord Byron*, 187–88.

[81] Byron, in *Medwin's Conversations of Lord Byron*, 188.

[82] Byron, *Letters and Journals*, ed. Leslie Marchand, 11:79, 105–106.

[83] Andreas Malm, *The Progress of this Storm: Nature and Society in a Warming World* (London: Verso, 2017), 149, 210. Malm repurposes Theodor Adorno's remark on progress in *History and Freedom: Lectures 1964–1965* (Cambridge: Polity, 2008), 143.

[84] Malm, *The Progress of this Storm*, 226–27, 230.

[85] Crutzen, 23. On the Anthropocene aesthetics of totality and dissipation on a planetary scale, see also Benjamin Morgan, "*Fin Du Globe*: On Decadent Planets," *Victorian Studies* 58 (2016): 609–635.

[86] Phoebe Wagner and Brontë Wieland, "New Project: Almanac for the Anthropocene: A Compendium of Solarpunk Futures," Wagner & Wieland, http://wagnerwieland.com/2019/06/03/new-project-almanac-for-the-anthropocene-a-compendium-of-solarpunk-futures/. See *Sunvault: Stories of Solarpunk and Eco-Speculation*, ed. Phoebe Wagner and Brontë Wieland (Nashville: Upper Rubber Boot Books, 2017), especially Joel Nathaniel's poetry in the volume, and the planned second volume *Almanac for the Anthropocene* (Morgantown: Univ. of West Virginia Press), to relate poetry to engineering blueprints and practical tools to fight "capitalism and climate disaster."

[87] See Marjorie Levinson's call for such a historical materialism in "Pre- and Post-Dialectical Materialism: Modeling Praxis without Subjects and Objects," *Culture Critique* 31 (1995): 111–27. On keeping the planet habitable, see David Wallace-Wells, *The Uninhabitable Earth: Life after Warming* (New York: Tim Duggan Books, 2019).