

Field Metallurgy and Ferrous Resource Scavenging in Post-Collapse Urban Environments

The Imperative of Post-Collapse Ferrous Metallurgy

In the aftermath of a catastrophic breakdown of global supply chains, centralized power grids, and industrial manufacturing, the remnants of urban infrastructure will transition from structural habitats into the primary repositories of raw materials. Among these materials, ferrous alloys—specifically steels of varying carbon concentrations—will become the most critical resources for the reconstruction of basic technologies, toolmaking, agriculture, and structural engineering. The ability to identify, scavenge, extract, and categorize these alloys without access to modern spectrographic equipment, such as X-ray fluorescence (XRF) or optical emission spectrometers (OES), represents a paramount operational skill for post-collapse metallurgical engineering.

Steel is fundamentally an alloy of iron and carbon, frequently modified with transition metals such as chromium, vanadium, manganese, and silicon to manipulate its mechanical properties¹. The carbon content remains the primary determinant of a steel's hardenability, which ultimately dictates its utility in a scavenging context. Low-carbon or "mild" steels, typically containing less than 0.30% carbon, possess high ductility, weldability, and toughness, but they cannot be hardened through traditional heating and quenching⁴. Consequently, mild steels are strictly relegated to structural applications, brackets, or improvised non-cutting hardware⁴.

Medium-carbon steels, ranging from 0.30% to 0.60% carbon, offer an optimal balance of toughness and hardenability, rendering them ideal for impact tools, axles, crowbars, and heavy-duty springs¹. High-carbon steels, possessing between 0.60% and 1.5% carbon, are capable of reaching the extreme hardness levels required for edge retention in cutting tools, files, and high-wear machinery components, though this hardness comes at the cost of inherent brittleness⁶.

The primary challenge in a resource-depleted environment lies in distinguishing the highly valuable high-carbon tool and spring steels from the ubiquitous oceans of mild structural steel⁴. This report details an exhaustive, multi-disciplinary methodology for the identification, safe extraction, and rigorous categorization of scavenged ferrous metals. The framework relies heavily on surviving industrial nomenclature, object recognition based on historical engineering applications, the physics of abrasive spark testing, magnetic and thermal phase transformations, empirical fracture analysis, and the evaluation of surface degradation mechanisms.

Pre-Scavenging Logistics: Extraction Tools and Occupational Hazards

Before metallurgical categorization can commence, the raw material must be liberated from its

original structural context. The collapse of electrical grids necessitates a reliance on manual extraction tools and the selective use of portable, battery-operated, or combustion-driven abrasive equipment.

The cold chisel is an indispensable tool for field extraction. Forged from medium-to-high carbon steel and hardened at the cutting edge, a cold chisel is designed to shear through unheated, lower-carbon metals, sever bolt heads, and split seized nuts⁹. The descriptor "cold" signifies that the target metal does not require preheating prior to shearing⁹. When paired with heavy striking tools, cold chisels provide a mechanical advantage for dismantling infrastructure where a hacksaw would bind or be too slow⁹. Angle grinders, equipped with abrasive cutting discs, remain the most efficient means of sectioning heavy steel, provided a portable power source is available¹¹.

However, the thermal processing and abrasive cutting of scavenged urban steel introduce severe occupational hazards, most notably related to protective zinc coatings. A vast percentage of structural mild steel is galvanized to prevent atmospheric corrosion¹². When galvanized steel is subjected to the intense heat of an abrasive cutting wheel, a cutting torch, or a blacksmith's forge, the zinc coating vaporizes. Inhalation of these volatile zinc oxides precipitates a severe physiological reaction known as zinc fume fever¹². Symptoms mimic acute influenza, including intense chills, fever, nausea, and myalgia¹². Because the post-collapse environment will likely lack advanced respiratory protection and medical support, the prevention of zinc exposure is critical. Prior to any high-temperature operation, galvanized coatings must be mechanically removed via cold grinding or chemically stripped by submerging the target area in weak acetic acid, such as household vinegar, until the zinc layer is entirely dissolved¹¹.

Industrial Nomenclature and Deciphering Surviving Markings

While visual and empirical tests are necessary for unidentifiable scrap, a significant volume of industrial steel retains stamped, painted, or cast nomenclature. Understanding historical engineering standards allows a scavenger to instantly bypass physical testing and ascertain the exact chemical composition of a billet or component. The European standard EN 10027 is one of the most comprehensive and widely encountered systems globally, alongside the American AISI/SAE system¹⁴.

According to EN 10027 Part 1, steels are divided into two primary groups based on their naming conventions. Group 1 steels are designated by their intended application and mechanical properties¹⁴. For example, structural steels are prefixed with the letter "S" (e.g., S235JR), where the subsequent digits represent the minimum yield strength in megapascals¹⁴. Group 2 steels are designated strictly by their chemical composition¹⁴. For unalloyed steels with an average manganese content below 1%, the designation begins with the letter "C" followed by a number representing the carbon content multiplied by 100¹⁴. Therefore, a stamped billet reading "C35" instantly identifies the material as a medium-carbon steel containing 0.35% carbon¹⁴. For alloyed steels where the content of any single alloying element exceeds 5%, the designation

begins with an "X" followed by the carbon content multiplied by 100, the chemical symbols of the alloying elements, and their respective percentages¹⁴. A stamp reading "X210Cr12" indicates a high-carbon tool steel containing approximately 2.10% carbon and 12% chromium, a highly valuable find for extreme wear applications¹⁸.

EN 10027 Part 2 establishes a numerical designation system formulated as "1.XXXX", where the initial "1." dictates that the material is steel (as opposed to "0." for cast iron or "3." for non-ferrous alloys)¹⁴. The subsequent digits define the specific alloy group and serial number¹⁴. If a scavenger locates a warehouse of bar stock stamped with "1.8159", reference to historical industrial knowledge reveals this to be an exceptional chromium-vanadium spring steel, identical to 51CrV4 or AISI 6150².

Object-Based Ferrous Taxonomy and Alloy Profiling

When nomenclature is absent, the scavenger must rely on object recognition. Modern industrial engineering demands highly specific material selection parameters to balance cost, machinability, and operational fatigue life²³. Consequently, the original function of a discarded mechanical component provides a high-probability baseline for its metallurgical composition.

Automotive and Transportation Scrap: The Spring Steels

Automotive suspension systems are universally recognized as the most abundant and accessible source of high-quality, medium-to-high carbon alloy steels in urban environments¹. These components are engineered to absorb massive kinetic energy, requiring exceptional toughness, high yield strength, and resistance to cyclic fatigue¹.

Heavy-Duty Leaf Springs Leaf springs, utilized predominantly in commercial freight trucks, off-road vehicles, and railway freight wagons, are generally manufactured from chromium-alloyed spring steels¹. A globally dominant standard for heavy-duty parabolic leaf springs is the aforementioned 51CrV4 (DIN 1.8159 or AISI 6150)¹. This specific alloy delivers remarkable mechanical performance due to its tightly controlled chemistry. The addition of vanadium acts as a powerful carbide former, which restricts austenite grain growth during high-temperature forging and heat treatment, thereby refining the final grain structure and significantly increasing the material's fatigue strength¹.

Another frequently encountered leaf spring alloy is AISI 5160 (EN 55Cr3 or DIN 1.7176)¹. This high-carbon chromium steel is the standard choice for heavy automotive applications in North American and European markets¹. It provides a forgiving heat treatment response, ensuring consistent hardening across thick cross-sections, and yields outstanding toughness when tempered correctly¹.

Coil Springs and Torsion Bars For heavy-duty coil springs, conical springs, and torsion bars, engineers frequently specify AISI 9260 (EN 61SiCr7 or DIN 1.7108), a silicon-chromium spring steel¹. The elevated silicon content in this alloy drastically raises the elastic limit of the steel, allowing it to undergo severe mechanical deflection without plastic deformation¹. This property makes 9260 highly desirable for the fabrication of long, flexible tools or implements subjected to heavy lateral bending forces¹.

Table 1: Chemical Composition of Primary Automotive Spring Steels

Steel Designation (AISI / EN / DIN)	Carbon (C) %	Chromium (Cr) %	Manganese (Mn) %	Silicon (Si) %	Vanadium (V) %
AISI 6150 / 51CrV4 / 1.8159	0.47 – 0.55	0.90 – 1.20	0.70 – 1.10	≤ 0.40	0.10 – 0.25
AISI 5160 / 55Cr3 / 1.7176	0.56 – 0.64	0.70 – 1.00	0.75 – 1.00	0.15 – 0.30	N/A
AISI 9260 / 61SiCr7 / 1.7108	0.56 – 0.64	0.20 – 0.40	0.70 – 1.00	1.80 – 2.20	N/A

(Data compiled from industrial metallurgical standards¹)

Industrial Bearings and Extreme Wear Steels

Roller bearings, ball bearings, and races salvaged from industrial machinery, automotive wheel hubs, and wind turbine gearboxes are subjected to immense contact pressures and sliding friction. To survive these conditions, bearings are manufactured almost exclusively from extreme-wear, high-carbon chromium steels, the most ubiquitous being AISI 52100 (EN 100Cr6 or DIN 1.3505)²⁸.

The chemistry of 52100 bearing steel typically features approximately 1.0% carbon and 1.5% chromium³¹. This composition yields exceptional surface hardness and abrasion resistance, making it theoretically ideal for edge tools³¹. However, 52100 poses severe challenges for field blacksmithing. Its high carbon and chromium matrix requires precise thermal control to forge without inducing catastrophic cracking, and it requires a delayed, slow quench in heated oil to harden safely³¹.

Furthermore, scavengers must be acutely aware of a microscopic degradation phenomenon unique to bearing steels known as rolling contact fatigue (RCF)³⁰. Prolonged cyclic stress creates subsurface microstructural anomalies known as White Etching Areas (WEA) or "butterfly" defects, named for their appearance under a microscope after chemical etching²⁸. These WEAs are zones where the martensitic matrix has been pulverized into a localized, ultra-fine nano-crystalline ferrite structure²⁸. Counterintuitively, empirical studies demonstrate that the WEA is depleted of carbon by approximately 27% compared to the surrounding parent material, yet it remains 17% harder, likely due to massive strain hardening and localized phase transformation²⁸. These intensely hard, carbon-depleted zones are frequently bordered by

micro-voids and stress fractures²⁸. If a salvaged bearing race is forged into a new tool without a thorough, high-temperature normalizing and annealing cycle to dissolve these defects and redistribute the carbon evenly into solution, the material will inevitably shatter during the quenching process²⁹.

Tool Steels: The Complexity of Salvaged Files

Hand files and rasps are among the most coveted items for post-collapse scavengers due to their historically high carbon content, frequently utilizing simple water-hardening tool steels like W1, which contains around 1.0% to 1.2% carbon³⁵. Industrial machine files or heavy-duty cutting dies may even be crafted from cold-work tool steels such as AISI D3 (DIN 1.2080 / X210Cr12)¹⁸. D3 steel is an oil-hardening alloy that contains up to 2.10% carbon and 12% chromium, providing staggering abrasion resistance but making it incredibly stiff under the forging hammer¹⁸.

However, the modern scavenger must exercise extreme caution, as the file industry utilizes two drastically different manufacturing methodologies: through-hardening and case-hardening³⁶. Older or high-quality industrial files (e.g., legacy Nicholson, Pferd, Simonds) are through-hardened, meaning the high-carbon steel composition is consistent from the surface to the core³⁶. In contrast, many modern budget files are manufactured from soft, low-carbon mild steel that is subsequently case-hardened in a carbon-rich atmosphere³⁵. Case-hardening diffuses a microscopic shell of carbon into the outer layer of the file, allowing the teeth to achieve high hardness³⁸. While this functions adequately for light abrasive tasks, once a scavenger grinds away the teeth or attempts to forge the file into a new shape, the thin high-carbon shell is destroyed, exposing the soft mild steel core³⁶. Tools forged from case-hardened files will fail to harden during quenching, rendering the scavenger's labor useless³⁶. Differentiating these two file types requires destructive testing, which will be detailed in the physical diagnostics section of this report.

Railway Infrastructure: Pearlitic Rails and Hadfield Frogs

Railway lines stretch across urban environments, offering thousands of tons of heavy steel. However, the metallurgical composition varies significantly depending on the specific component of the track system.

Standard Pearlitic Rails Modern longitudinal railway tracks are generally manufactured from high-carbon, pearlitic steel grades optimized for heavy-haul service and wear resistance. A dominant European standard is grade R260 (EN 13674-1)⁴⁰. R260 contains approximately 0.62% to 0.80% carbon and 0.90% to 1.20% manganese, with a maximum of 0.50% silicon⁴⁰. The elevated carbon and manganese levels yield a highly robust, impact-resistant steel that behaves similarly to a 1070 or 1080 series carbon steel, making railway tracks an excellent source material for heavy anvils, striking tools, and thick-bladed implements⁴¹.

Railway Frogs: The Hadfield Manganese Anomaly The intersection points of railway tracks, known as frogs or crossings, are subjected to catastrophic impact forces from train wheels traversing the gaps. Standard pearlitic rail steel would deform or fracture under these localized loads. Therefore, railway frogs, along with rock crusher jaws and heavy excavator bucket teeth, are frequently cast from a highly specialized alloy known as Hadfield austenitic manganese

steel³.

Invented in 1882, Hadfield steel boasts a nominal composition of 1.0% to 1.4% carbon and 10% to 14% manganese, ideally maintaining a manganese-to-carbon ratio of 10:1³. This alloy possesses an extraordinary capacity for dynamic work-hardening³. Under severe impact loading, the surface of the steel rapidly strain-hardens—driven by dislocation mechanisms, deformation twinning, and dynamic strain aging—transitioning from a relatively soft initial state to extreme hardness, while the core remains highly ductile and tough³.

However, Hadfield steel is the bane of the post-collapse blacksmith. The massive concentration of manganese acts as a powerful austenite stabilizer, depressing the martensite transformation temperature so severely that the steel remains entirely in the austenitic phase (face-centered cubic) at room temperature⁴⁵. Consequently, Hadfield steel is completely non-magnetic³.

Furthermore, it cannot be hardened by heating and quenching; it only hardens through physical impact⁴⁵. Attempting to cut Hadfield steel with a hacksaw or file is futile, as the friction of the tool instantly work-hardens the surface, destroying the cutting teeth³. Modern foundries utilize Thermal Mechanical Control Processes (TMCP) to refine the coarse grain structure of cast Hadfield steel, but these techniques require precise industrial control beyond the capabilities of field scavenging⁴⁶. If a scavenger identifies a component as Hadfield steel, it should be utilized strictly in its existing cast shape for impact applications.

Visual Spectrometry: The Physics of the Spark Test

When nomenclature is absent and object recognition is ambiguous, the abrasive spark test remains the most reliable, rapid, and field-expedient diagnostic method for estimating the carbon content and alloy family of a ferrous metal²⁴. The procedure entails pressing a metal sample against a high-speed abrasive grinding wheel—ideally a bench grinder or angle grinder equipped with a 24- to 80-grit carborundum wheel—and meticulously analyzing the resulting trajectory, color, and morphology of the emitted spark stream²⁴.

Thermodynamics and Oxidation Kinetics of the Spark Stream

The visual phenomenon of the spark test is not merely the friction of hot metal; it is governed by the complex physical chemistry of high-temperature oxidation and carbon combustion. When the abrasive wheel shears micro-particles of steel from the sample, mechanical friction and plastic deformation heat the debris to incandescence²⁴. Ejected into the oxygen-rich atmosphere at high velocity, the exposed iron rapidly oxidizes⁵². This oxidation is a highly exothermic reaction, generating sufficient internal heat to maintain the particle's incandescence along its flight path⁵². Laboratory analysis of spark debris confirms an oxidation

sequence transitioning from ferrous oxide (FeO) to ferroferric oxide (Fe_3O_4), and ultimately to ferric oxide (Fe_2O_3) as the particle cools⁵².

The most critical diagnostic feature of the spark test is the morphological event known as the "carbon burst." As the iron oxidizes, the ambient oxygen penetrates the semi-molten oxide shell of the particle and reacts with the carbon (existing in the steel matrix as iron carbide, Fe_3C

)⁵². This reduction reaction generates carbon monoxide (CO) gas⁵². Because the CO is trapped within the rapidly solidifying oxide shell, internal pressure builds exponentially until it forcefully ruptures the particle⁵². This microscopic explosion visibly manifests as a branching burst, fork, or starburst in the spark stream⁵².

Therefore, a direct, proportional relationship governs the test: the higher the carbon content of the steel, the greater the volume of CO gas generated, resulting in a higher frequency, complexity, and kinetic intensity of the spark bursts⁶. As carbon content increases past 0.6%, the quantity of pure iron phase in the debris drops significantly, replaced by dense, explosive networks of oxide and voided spherical residues left by the carbon bursts⁵².

Standardized Execution and Environmental Control

To ensure diagnostic accuracy, the practitioner must rigorously standardize the testing environment:

1. **Optical Control:** The test must be conducted in subdued or dim lighting. Bright ambient sunlight washes out the lower-temperature thermal radiation of the sparks, obscuring critical color variations in the red and orange spectrums²⁴.
2. **Surface Decontamination:** The operator must heavily grind past any surface coatings, paint, rust, or decarburized layers to ensure the sparks represent the chemical composition of the core base metal²⁴.
3. **Pressure Modulation:** Light, consistent pressure against the wheel at a 45-degree angle is required. Excessive physical pressure induces frictional overheating, which artificially elongates the spark stream and distorts the natural burst pattern⁶.
4. **Calibration via Reference:** Human memory of spark patterns is highly subjective. The observer must continually calibrate their visual baseline by testing scrap pieces of known provenance (e.g., a verified piece of 1018 mild steel and 1084 high-carbon steel) immediately alongside the unknown sample⁴.

Interpreting Spark Characteristics

The anatomy of a spark stream is divided into three zones: the root (immediately adjacent to the wheel), the middle (the primary carrier lines), and the tail (the terminus of the trajectory)²⁴. The practitioner evaluates four primary metrics: carrier line length, color, burst morphology (branching), and total stream volume⁶.

Wrought Iron and Mild Steel Wrought iron and low-carbon structural steels (e.g., A36, unalloyed bars) produce long, continuous, and straight carrier lines that travel significantly away from the grinding wheel⁶. Because the carbon content is extremely low (typically

<0.30%), there is insufficient carbon to generate the CO gas required for complex explosions. The sparks appear bright white or yellowish, terminating in simple, tiny, single-forked bursts or fading out completely as straight lines⁶. The overall volume of the stream is moderate⁵⁷.

Medium-Carbon Steel Steels such as 51CrV4 leaf springs or 1045 axles produce a noticeably denser volume of sparks than mild steel⁵⁷. The carrier lines are of moderate length⁶. The critical distinction is the frequency and complexity of the bursts; the single forks of mild steel transition

into more frequent bursts that begin to exhibit secondary branching, resembling small starbursts⁵¹. The color remains predominantly bright white, occasionally displaying a slight orange tint if alloying elements are present⁶.

High-Carbon and Tool Steel Steels such as 1095, 52100 bearings, and W1 file steel produce radically different, highly distinctive spark streams⁶. The carrier lines are significantly truncated. The immense concentration of carbon causes the particles to explode rapidly and violently shortly after leaving the wheel⁶. The stream is characterized by brilliant, dense, repeating starbursts and highly complex, bushy micro-explosions⁷. The volume of sparks is exceptionally high, creating a dense, energetic spray that resembles a localized firework display⁷.

Influence of Alloy Modifiers Heavy alloying elements alter the thermodynamic behavior of the spark, overriding or modifying the base carbon signature:

- *Chromium:* Chromium acts to suppress the overall length of the spark stream and dampens the intensity of the carbon bursts. It imparts a distinct orange or reddish color to the carrier lines²³. Steels like D3 tool steel or 52100 bearings will show slightly subdued bursts compared to plain high-carbon steel, despite their high carbon content, due to the stabilizing effect of complex chromium carbides²³.
- *Stainless Steel:* Austenitic and martensitic stainless steels produce a short, bushy stream that is noticeably yellow or straw-colored. Despite sometimes containing moderate carbon, they exhibit very few traditional carbon bursts, appearing more like a glowing bush of continuous lines⁶.
- *Cast Iron:* Gray and white cast irons produce a very short, low-volume, dull red-to-orange stream⁵⁰. Because of the massive concentration of graphite flakes or cementite networks, the sparks barely leave the wheel before terminating in very fine, complex, feathery bursts located almost immediately at the grinding surface⁵⁰.

Table 2: Diagnostic Spark Test Profiles of Ferrous Alloys

Material Classification	Stream Length	Primary Color	Burst Morphology & Complexity	Stream Volume / Density
Wrought Iron	Very Long	Light Straw / White	Straight, continuous lines; negligible forks.	Low
Mild Steel (<0.30% C)	Long	Bright White	Simple, tiny forks at the tail end.	Moderate
Medium Carbon	Medium	Bright White	Frequent bursts;	Dense

(0.3-0.6% C)			appearance of secondary branching.	
High Carbon (>0.60% C)	Short	Brilliant White	Bushy, complex, repeating starbursts and micro-explosions.	Very High
High Chromium (e.g., 52100)	Short	Orange / Red tint	Suppressed carbon bursts due to chromium carbides.	High
Cast Iron	Very Short	Dull Red / Orange	Feathery, highly complex fine bursts tight to the wheel.	Low / Moderate
Stainless Steel	Medium	Yellow / Straw	Bushy appearance; lack of distinct starburst explosions.	Low

(Data synthesized from metallurgical screening protocols⁶⁾)

Magnetic Phase Transformations and Thermal Diagnostics

Magnetism is a fundamental property of iron, but it is heavily dependent on the crystal lattice structure and ambient temperature. Understanding these phase transitions is critical for both the diagnostic identification of alloys (such as Hadfield steel) and the precise control of field heat treatments.

At ambient temperatures, the atomic structure of standard carbon steel is arranged in a

body-centered cubic (BCC) geometric pattern, known metallurgically as α -iron or ferrite⁶⁰. In

this BCC phase, the material is strongly ferromagnetic⁶⁰.

As the steel is heated in a forge, it undergoes thermal expansion and increased atomic vibration. Eventually, it reaches a thermal threshold where the kinetic energy of the atoms overwhelms the alignment of the magnetic domains, causing the material to lose its

ferromagnetism⁶¹. This temperature, theoretically fixed at $770^{\circ}C$ ($1420^{\circ}F$) for pure iron, is known as the Curie point⁶⁰. In the context of the iron-carbon phase diagram, the Curie temperature corresponds to the A_2 transformation line⁶⁰.

As heating continues just past the Curie point, crossing the A_3 or A_{cm} phase boundary lines (depending on whether the steel is hypoeutectoid or hypereutectoid, typically between $780^{\circ}C$ and $850^{\circ}C$), the steel undergoes an allotropic transformation⁶⁰. The BCC lattice

violently shifts into a denser face-centered cubic (FCC) lattice known as γ -iron, or austenite⁶⁰. Austenite is entirely non-magnetic and is the required phase for dissolving carbon into solid solution prior to quench-hardening⁶⁰.

Practical Field Diagnostics via Magnetism This physical transition provides post-collapse blacksmiths with an infallible, battery-free pyrometer. By touching a simple magnet to the heated steel in the forge, the operator can pinpoint the exact moment the steel crosses

$770^{\circ}C$ ⁶⁰. When the magnet ceases to attract the steel ("goes non-magnetic"), the operator knows the steel has transitioned into austenite and is nearing the optimal critical temperature for quench-hardening⁶³. If a sample of scavenged mystery steel hardens successfully after being quenched from just above its non-magnetic state, its status as a high-carbon or alloy steel is empirically confirmed²⁴.

Conversely, the magnet test serves as an exclusionary diagnostic tool at room temperature⁸. As previously detailed, if a heavy, structural steel component (such as a railway frog) is entirely non-magnetic at ambient temperatures, it is almost certainly Hadfield high-manganese steel, which retains its FCC austenitic structure at room temperature due to its extreme manganese alloying³.

Surface Degradation, Atmospheric Fatigue, and False Negatives

Scavenged steel is rarely in pristine condition. Post-collapse operators must understand how environmental exposure, atmospheric corrosion, and prior industrial processing alter the physical properties of the metal, often resulting in false-negative identification during spark or hardness testing.

The Dynamics of Decarburization

Decarburization is the insidious depletion of carbon atoms from the surface layers of a steel component. This phenomenon occurs when the metal is exposed to high temperatures in environments rich in oxygen, hydrogen, or water vapor⁶⁶. In a scavenging context, this is

frequently encountered on components that have survived structural fires, or on hot-rolled industrial bar stock where the decarburized skin was never milled away⁶⁷.

At elevated temperatures (typically above 700°C), the chemical potential of carbon in the ambient atmosphere is lower than that within the steel⁶⁷. Carbon atoms residing within the austenite lattice diffuse rapidly toward the surface, driven by this concentration gradient⁷⁰. Upon reaching the surface, the carbon reacts with atmospheric oxygen or steam to form volatile carbon dioxide (CO_2) or carbon monoxide (CO) gases, which readily escape⁷¹. The rate of this carbon diffusion into the atmosphere is governed by Fick's laws of diffusion.

The diffusion coefficient D of carbon in austenite can be expressed mathematically as:

$$D = D_0 \exp\left(-\frac{Q}{RT}\right)$$

where D_0 is the pre-exponential factor, Q is the activation energy for carbon diffusion in austenite, R is the ideal gas constant, and T is the absolute temperature⁷¹. This process leaves the steel with a highly distinct microstructural gradient: the extreme outer surface becomes pure, soft ferrite (entirely devoid of carbon), transitioning inward to a mixture of Widmanstätten ferrite and pearlite, and finally returning to the unaffected high-carbon core⁷⁰.

Field Implications of Decarburized Layers Decarburization severely degrades the mechanical properties of the steel, drastically lowering surface hardness, wear resistance, and fatigue strength⁶⁶. If a scavenger performs a spark test or a file test on the outer surface of a heavily decarburized automotive spring, the surface will behave exactly like mild steel⁶⁷. The sparks will be long and devoid of carbon bursts, and a file will easily bite into the soft ferrite skin⁵⁵. This false negative frequently leads to the erroneous discarding of premium high-carbon alloy steel. To mitigate this, the operator must aggressively grind past the "decarb layer" before performing any diagnostic testing²⁴. Depending on the thermal history of the steel, this layer can range from 0.5 mm to over 2.0 mm deep⁷¹. Once 1 mm to 2 mm of the outer skin is removed via a grinding wheel, a subsequent spark test on the freshly exposed core will reveal the true carbon burst signature of the base alloy⁶⁸.

Hardness Verification and Field Heat Treatment Protocols

The final, definitive step in the identification of scavenged steel is the empirical verification of its heat treatment response²⁴. Once a piece of steel has been tentatively identified via object recognition, spark testing, and magnetic behavior, the operator must subject a small, isolated test coupon to a full thermal cycle to confirm the presence of martensite²⁴.

The File Skating Test and Empirical Hardness

Without access to a calibrated Rockwell C (HRC) or Brinell (BHN) hardness testing machine, field metallurgists rely on the file skating test⁷³. This test uses a high-quality, known through-hardened file (typically possessing a baseline hardness of 60–65 HRC) as a comparative benchmark³⁶. By firmly sliding the file across the surface of the unknown, heat-treated steel, the operator assesses the acoustic feedback and mechanical "bite"³⁶. If the file easily bites into the metal, removing ribbons of material, the sample is soft (e.g., annealed steel, mild steel, or a decarburized layer, typically under 40 HRC)⁷². Conversely, if the file fails to cut and instead slides frictionlessly across the surface with a high-pitched, glassy sound—a phenomenon known as "skating"—the material is highly hardened, indicating a successful martensitic transformation (approaching or exceeding 60 HRC)²⁴. For more granular analysis, scavengers can utilize graduated hardness file sets, which contain files tempered to specific intervals (e.g., 40, 45, 50, 55, and 60 HRC), to accurately bracket the hardness of salvaged components⁷⁵.

Fracture Analysis of Salvaged Files

As previously discussed, differentiating a through-hardened high-carbon file from a case-hardened mild steel file is critical before committing labor to forging³⁵. This is achieved via a destructive fracture test. The practitioner clamps the terminal end of the file in a heavy vise and strikes it sharply with a hammer to induce a brittle fracture³⁶.

- **Through-Hardened High-Carbon Steel:** The file will snap cleanly with an audible crack and minimal plastic deformation. Inspection of the cross-sectional fracture surface will reveal a uniform, exceptionally fine, silky gray crystalline grain structure extending perfectly from the edge to the core³⁵.
- **Case-Hardened Mild Steel:** The file will exhibit slight bending or tearing before fracturing. The fracture surface will display a distinct visual discrepancy: a thin, glassy outer ring (the hardened carbon case) surrounding a coarse, shiny, fibrous core of softer, low-carbon mild steel³⁶.

The Verification Heat Treatment Cycle

To definitively confirm the carbon content of an unknown sample, the scavenger must perform a controlled thermal cycle:

1. **Thermal Normalization:** The test coupon is heated in the forge past its Curie point to a full austenitic state (non-magnetic, typically a bright cherry red color)⁶⁰. It is then removed and allowed to cool slowly in still, ambient air. This normalizes the steel, relieving internal forging stresses and creating a uniform grain structure⁶⁵.
2. **Quenching:** The sample is re-heated to the non-magnetic austenitizing temperature. Because the exact alloy and its corresponding time-temperature-transformation (TTT) curve are unknown, operators should default to quenching in a warm, low-viscosity fluid, such as canola oil or kerosene³⁵. Quenching an unknown high-carbon or heavily alloyed steel in water is highly aggressive and frequently induces catastrophic thermal shock and quench cracking³⁶.

3. **Martensite Verification:** Once the sample has cooled to ambient temperature in the oil, it is wiped clean and subjected to the file test²⁴. If the test file skates effortlessly across the newly quenched surface without biting, the formation of hard martensite is confirmed, definitively classifying the material as high-carbon or a hardenable alloy steel⁵. If the file bites deeply, the carbon content is insufficient for toolmaking, and the material must be relegated to mild structural applications⁵.
4. **Tempering and Bend Testing:** Untempered martensite is highly stressed and dangerously brittle; it will shatter like glass under impact³⁶. The practitioner must immediately temper the test piece by reheating it to a low, controlled temperature (e.g., $200^{\circ}C$ / $400^{\circ}F$, often indicated by a light straw oxide color on polished steel) for one to two hours²⁴. This converts the brittle matrix into tougher, tempered martensite⁵. The coupon is then subjected to a destructive bend test in a vise. A quality high-carbon steel tool will flex under pressure and return to true, or eventually snap sharply under extreme force, whereas mild steel will merely deform plastically²⁴.

Synthesis and Post-Collapse Metallurgical Strategy

The extraction, categorization, and utilization of ferrous resources in a post-collapse urban environment depend entirely on the operator's metallurgical literacy. The loss of industrial infrastructure and chemical spectrometry does not render advanced materials unidentifiable; the physical, thermodynamic, and mechanical properties of iron-carbon alloys remain constant and highly exploitable.

By integrating historical object recognition to target high-yield components like 51CrV4 leaf springs and W1 files, decoding surviving EN 10027 industrial nomenclature, and executing the abrasive spark test to visually analyze the thermodynamics of carbon combustion bursts, a practitioner can rapidly screen raw materials. Furthermore, by utilizing the magnetic Curie-point phase transitions for thermal control, grinding past decarburized surface layers to avoid false negatives, and empirically verifying martensitic transformation through systematic quench-and-file testing, the scavenger can accurately separate invaluable high-carbon tool steels from mild structural alloys. Mastery of these field-expedient methodologies ensures the continuous, sustainable fabrication of resilient tools and structural components necessary for survival and reconstruction.

Works cited

1. Spring Steel Industry Guide, <https://www.fushunspecialsteel.com/spring-steel-industry-guide/>
2. 51CrV4, 50CrV4, 1.8159, AISI 6150 - spring steel - VIRGAMET, <https://virgamet.com/offer/strips-coils-51crv4-50crv4-58crv4-59crv4-50cv4-51cv4-spring-steel>
3. An overview on high manganese steel casting | Request PDF, https://www.researchgate.net/publication/286741705_An_overview_on_high_manganese_steel_casting
4. experimental analysis & determination of various plain carbon steels,

https://www.researchgate.net/publication/316476322_EXPERIMENTAL_ANALYSIS_DETERMINATION_OF_VARIOUS_PLAIN_CARBON_STEELS_BY_USING_SPARK_TESTING

5. How do you tell if steel has been hardened? - Quora,
<https://www.quora.com/How-do-you-tell-if-steel-has-been-hardened>
6. Comprehensive Guide to Spark Testing for Metals and Cables,
<https://shop.machinemfg.com/what-is-the-spark-test/>
7. Determining carbon content in steels and alloys: the spark method,
<https://www.pzps.tech/en/articles/opredelenie-soderzhaniya-ugleroda-v-stalyah-i-splavah-iskrovoy-metod>
8. How to Identify an Unknown Metal: Magnet, Spark, Density and,
<https://oceanplayer.com/how-to-identify-an-unknown-metal-magnet-spark-density-and-color-tests/>
9. Cold Chisels | Tameson.com, <https://tameson.com/pages/cold-chisel-tool>
10. Cold Chisel - toolhound.net, <https://www.toolhound.net/tool/cold-chisel>
11. Derusting Tools - Holger Clasen,
<https://www.holger-clasen.de/en/products/surface-treatment/rust-removal-tools/>
12. How Everyday Products Make People Sick - dokumen.pub,
<https://dokumen.pub/download/how-everyday-products-make-people-sick-updated-and-expanded-toxins-at-home-and-in-the-workplace-9780520945319.html>
13. Full text of "Taylors Principles And Practice Of Medical Jurisprudence,
https://archive.org/stream/in.ernet.dli.2015.112365/2015.112365.Taylors-Principles-And-Practice-Of-Medical-Jurisprudence-Twelfth-Edition_djvu.txt
14. Steel Grade Designation System in accordance with the European,
<https://bmcmetals.lv/en/standards/steel-grade-designation-system-in-accordance-with-the-european-standards.html>
15. Steel Naming Conventions | PPTX - Slideshare,
<https://www.slideshare.net/slideshow/steel-naming-conventions/13512177>
16. Standardized Steel Designation Guide | PDF - Scribd,
<https://www.scribd.com/document/960995174/NF-EN-10027>
17. Structural Steel Plate Specifications | PDF - Scribd,
<https://www.scribd.com/document/378559899/Material-Spec>
18. AISI D3, DIN 1.2080 / X210CrW12, AFNOR Z210W12-01, HCHCR,
<https://www.newarisemetal.com/r/tool/din-1-2080-aisi-d3-x210crw12-round-bars>
19. D3 Cold Work Steel | 1.2080 | X210Cr12 | SKD1 - Otai Special Steel,
<https://www.astmsteel.com/product/d3-cold-work-steel-1-2080-x210cr12-skd1/>
20. European Steel and Alloy Grades / Numbers - free database for search,
<https://www.steelnumber.com/>
21. Stress-Shot-Peened Leaf Springs Material Analysis through Nano,
<https://www.mdpi.com/1996-1944/14/17/4795>
22. AISI 6150 Steel | 1.8159 | 51CrV4 | Sup10 Spring Steel,
<https://www.astmsteel.com/product/aisi-6150-steel/>
23. How to Identify Scrap Metals - 911Metallurgist,
<https://www.911metallurgist.com/blog/identifying-scrap-metals/>

24. knife steel heat treat - Brunskogs Smide,
<https://www.brunskogssmide.se/info-sida/>
25. RAILWAY SPRINGS - Federnwerk Bischoff - Production and,
<https://www.federnwerk-bischoff.com/products/rail-springs>
26. (PDF) Fatigue Crack Propagation of 51CrV4 Steels for Leaf Springs,
https://www.researchgate.net/publication/379745301_Fatigue_Crack_Propagation_of_51CrV4_Steels_for_Leaf_Springs_Suspensions_of_Railway_Freight_Wagons
27. EN47 / 50CrV4 / 51CrV4 / AISI 6150 / DIN 8159 / SUP10 | Spring Steel,
<https://venturasteels.com/products/spring-steel/en47>
28. Redistribution of carbon caused by butterfly defects in bearing steels,
https://www.researchgate.net/publication/337204522_Redistribution_of_carbon_caused_by_butterfly_defects_in_bearing_steels
29. International Journal of Fatigue - RWTH Publications,
<https://publications.rwth-aachen.de/record/988197/files/988197.pdf>
30. White Structure Flaking in Rolling Bearings for Wind Turbine,
<https://www.windsystemsmag.com/white-structure-flaking-in-rolling-bearings-for-wind-turbine-gearboxes/>
31. Tribological Response of Heat Treated AISI 52100 Steels Against,
https://www.researchgate.net/publication/320231025_Tribological_Response_of_Heat_Treated_AISI_52100_Steels_Against_Steel_and_Ceramic_Counterparts
32. Investigations on Tailored Forming of AISI 52100 as Rolling Bearing,
<https://www.mdpi.com/2075-4701/10/10/1363>
33. Bearing Steel Technology | PDF - Scribd,
<https://www.scribd.com/doc/151274363/114508321-Bearing-Steel-Technology>
34. University of Southampton Research Repository,
https://eprints.soton.ac.uk/473863/1/Mostafa_Ellaithy_PhD_Thesis.pdf
35. Hardening of file-steel : r/Blacksmith - Reddit,
https://www.reddit.com/r/Blacksmith/comments/17mdnrt/hardening_of_filesteel/
36. What Steel Are Files Made Of? High-Carbon File Steel Explained,
<https://machininganswers.com/what-steel-are-files-made-of/>
37. D3 Tool Steel 1.2080 - AKM Steels, <https://akmsteels.co.uk/grades/d3-tool-steel/>
38. What Does Case Hardened Mean for Machine Parts? - uneed,
<https://www.uneedpm.com/what-does-case-hardened-mean-for-machine-parts/>
39. Hardening Mild Steel - Heat Treating, general discussion - I Forge Iron,
<https://www.iforgeiron.com/topic/4203-hardening-mild-steel/>
40. COMPOSITION (WT.%) OF UIC54 R260 RAIL STEEL USED IN,
https://www.researchgate.net/figure/COMPOSITION-WT-OF-UIC54-R260-RAIL-STEEL-USED-IN-EXPERIMENTS_tbl1_399520202
41. What steel are rails made of? - Knowledge - GNEE,
<https://www.chinarailfastener.com/info/what-steel-are-rails-made-of-103353321.html>
42. Chemical properties of Rails - ArcelorMittal,
<https://rails.arcelormittal.com/products/transport-rails/chemical-composition/>
43. What Grade of Steel Is Railroad Track? 1084, Carbon Content & Rail,

- <https://machininganswers.com/what-grade-of-steel-is-railroad-track/>
44. Hadfield Manganese Steel - IspatGuru,
<https://www.ispatguru.com/hadfield-manganese-steel/>
 45. Hadfield Steel in Mining Applications | PDF - Scribd,
<https://www.scribd.com/document/946983799/Prominence-of-Hadfield-Steel-in-Mining-and-Mineral>
 46. Hadfield manganese austenitic steel: A review of manufacturing,
https://www.researchgate.net/publication/335498346_Hadfield_manganese_austenitic_steel_A_review_of_manufacturing_processes_and_properties
 47. Advanced Materials & Technologies - ISMAN,
https://www.ism.ac.ru/events/EPNM2018/AMT_3_2018.pdf
 48. Old Meetings: PLASMA99,
<http://old.ichmt.org/abstracts/Plasma99/poster-session.html>
 49. Spark Test Analysis of Steel Types | PDF - Scribd,
<https://www.scribd.com/document/957800000/Types-of-steel-by-spark>
 50. Cast Iron vs Cast Steel: How to Identify These Metals - EPCLand,
<https://epcland.com/cast-iron-vs-cast-steel/>
 51. Spark Testing for Metal Identification | PDF - Scribd,
<https://www.scribd.com/document/440154945/Spark-Test-Materials-Engineering>
 52. Study on the Mechanism of Carbon Steel Sparks - ResearchGate,
https://www.researchgate.net/publication/331983775_Study_on_the_Mechanism_of_Carbon_Steel_Sparks
 53. Kinetics of the oxidation of iron carbide dispersed in a carbon matrix,
<https://pubmed.ncbi.nlm.nih.gov/19338325/>
 54. The carburization of iron oxide with carbon monoxide - ResearchGate,
https://www.researchgate.net/publication/250593771_The_carburization_of_iron_oxide_with_carbon_monoxide_Modifications_of_hagg_iron_carbide
 55. Spark Testing of Steels - IspatGuru,
<https://www.ispatguru.com/spark-testing-of-steels/>
 56. Environmental STEM Study of the Oxidation Mechanism for Iron and,
<https://www.mdpi.com/1996-1944/15/4/1557>
 57. Comprehensive Guide to Spark Testing for Metal Identification,
<https://shop.machinemfg.com/comprehensive-guide-to-spark-testing-for-metal-identification/>
 58. Spark testing - Wikipedia, https://en.wikipedia.org/wiki/Spark_testing
 59. Spark Testing - Cape Forge, <http://www.capeforge.com/Spark%20testing.html>
 60. Chapter 1 - Rewon Engineering,
https://rewon.com.my/ferrous_data/chapter_1.htm
 61. Magnets in Bladesmithing | Apex Magnets Blog,
<https://www.apexmagnets.com/news-how-to/magnets-in-bladesmithing/>
 62. Can You Trust Your Magnet During Heat Treating? - Knife Steel Nerds,
<https://knifesteelnerds.com/2019/03/18/magnet-heat-treating/>
 63. Something weird happens at 770°C - YouTube,
<https://www.youtube.com/watch?v=XblWmVXZOFE>
 64. Something weird happens at 770°C. (Thought some of you might,

- https://www.reddit.com/r/Bladesmith/comments/1hg4w88/something_weird_happens_at_770c_thought_some_of/
65. Jon Pearce – Making Woodturning Tools | South Auckland,
<https://sawg.org.nz/jon-pearce-making-woodturning-tools/>
 66. The Fastener Decarburization of Steel: How To Avoid It,
<https://www.lsfe.com/fastener-decarburization-explained/>
 67. Understanding and Preventing Steel Decarburization, Part 1,
<https://www.wasatchsteel.com/understanding-and-preventing-steel-decarburization-part-1/>
 68. (PDF) Understanding and measuring decarburization - ResearchGate,
https://www.researchgate.net/publication/286099499_Understanding_and_measuring_decarburization_Understanding_the_forces_behind_decarburization_is_the_first_step_toward_minimizing_its_detrimental_effects
 69. How is decarburization evaluated? Presented by David Pye,
<https://themonty.com/how-is-decarburization-evaluated-presented-by-david-pye/>
 70. Decarburisation of steel,
<https://www.phase-trans.msm.cam.ac.uk/abstracts/M0.html>
 71. Calculating decarburization | Thermal Processing Magazine,
<https://thermalprocessing.com/calculating-decarburization/>
 72. What Is Decarburization? - Kluthe Magazine,
<https://kluthe.com/magazin/en/what-is-decarburization/>
 73. Comprehensive Guide to Steel Files for Blacksmithing - MFG Shop,
<https://shop.machinemfg.com/comprehensive-guide-to-steel-files-for-blacksmithing/>
 74. How to Heat Treat Steel: 2025 Complete Guide - uneed,
<https://www.uneedpm.com/how-to-heat-treat-steel-2025-complete-guide/>
 75. Sword Blade Hardness: the current research - myArmoury.com,
https://myarmoury.com/feature_bladehardness.html
 76. How would you further machine this? : r/Machinists - Reddit,
https://www.reddit.com/r/Machinists/comments/1twlqgp/how_would_you_further_machine_this/
 77. How to Check the Hardness of Metal (Complete Practical Guide),
<https://machininganswers.com/how-to-check-the-hardness-of-metal/>