REPORT

The Aluminum Association

Annual Summary Report on Molten Metal Incidents in 2024

September 2025

For the year 2024, 141 molten metal incident reports occurring world-wide were received as compared to 156 reports for 2023, 198 reports for 2022, and 140 reports for 2021. The attached figures summarize the reports for 2024 as well as the data for the years 1980 through 2024.

SUMMARY POINTS:

- **For 2024, there were 141 explosion incidents reported. This was lower than the 156 incidents for 2023 and considerably lower than the 198-record number of incidents reported in 2022. The 141 total 2024 incidents are lower than the average 161 reported incidents for the 5 previous years, 2019 through 2023.**
- **Unlike the previous two years with 0 Force 3 reported explosions, in 2024 there were 2 Force 3 incidents. The previous 5 years, 2019 through 2023, averaged 0.6 Force 3 explosions per year.**
- **There were 112 Force 1 explosions, 27 Force 2 explosions, and 2 Force 3 explosions reported in 2024.**
- **Both Force 3 explosions occurred internationally, and government reports were used to ascertain the incident information. Both Force 3 incidents occurred during billet steady state casting. These two incidents resulted in 7 Fatalities, 1 Serious injury, and 14 Minor injuries.**
- **The upward trend in Force 2 explosions, which commenced in 2016, persisted into 2024, averaging 22 incidents per year from 2016 to 2024. This nine-year period marked a reversal of the previous decline that began around 2008 and continued through 2014.**
- **Over the past decade, Force 2 explosions have constituted an increasing proportion relative to Force 1 and Force 3 events. In 2024, Force 2 explosions accounted for 19% of all reported cases, representing the highest percentage recorded since 2009 (34.9%).**
- **A new chart (Figure 4) was added that provides the % Force 1 and 2 Incidents for the years 2000 through 2024 and maps the upward trend of Force 2 incidents over the last 10 years.**
- **There were 29 Melting incidents, representing the lowest annual total since 2013, with 27 reported incidents. This figure is significantly below the average of 53 annual Melting incidents observed from 2014 to 2023. Notably, 10 of the 29 incidents were classified as Force 2, with no Force 3 incidents reported.**
- **A high majority (19) of the Melting incidents were related to scrap charging, with eight being Force 2.**
- **Over the entire timeframe of the Incident Report (1980 through 2024) the highest number of incidents occur during the Casting process, however Melting explosions have the highest percentage of Force 2 and 3 incidents (27% and 5% respectively).**

- **The Melting Injury Rate has continued to be very low in 2024 (0.0%) with zero injuries in 2024. It has been very low for the last 15 years (< 0.05), except for 2015 (>0.7), which had 35 Minor injuries, resulting from one Force 3 explosion.**
- **A significant number of Casting and Transfer explosions continue to be related to wet/rusty drain pans. In 2024 for DC Casting, wet/rusty drain pans at end of cast or during start-up aborts accounted for the highest number of incidents (13), with seven being Force 2. For Transfer incidents from 2008 to 2024, wet/rusty drain pans are the leading category for Force 1, 2, & 3 explosions (154) followed closely by wet tools (144). For Force 2 & 3 explosions, wet/rusty drain pans account for 19 of the 33 incidents.**
- **When only looking at Force 2 and Force 3 Casting explosions from 2015 through 2024, the highest number of explosions (22) are due to wet/rusty drain pans occurring at VDC cast Termination and aborts, which occur typically during Cast Start. These are followed by VDC Cast Start explosions due to excessive curl, hang-ups, and bleed-outs (19).**
- **When combining Casting and Transfer 2024 incident data for wet/rusty drain pans, this source of explosions accounts for 18% (19 of 103) of all the explosions in these two operations. In 2022 and 2023, this rate was 20%.**
- **As indicated in the past, a significant number of injuries have occurred in relatively straightforward Transfer operations, including 82 Serious injuries and seven Fatalities. Of note, however in 2024, there were only three Transfer injuries, all Minor, zero Serious and zero Fatal injuries. And the Transfer Injury rate has been trending downward, especially in the last 12 years.**
- **With the two Force 3 Casting explosions and the multiple Fatal, Serious, and Minor injuries associated with these two Force 3 incidents, there is a large increase in the Casting injury rate in 2024.**
- **The general Injury Rate trends over the last 35 years have certainly been downward; however, the data is scattered as evidenced by very low R2 values shown in the three Injuries per Incident graphs.**
- **The injury rate per incident has been trending downward over the past 5-10 years for all three operations: Melting, Casting, and Transfer, but this was reversed for Casting in 2024 due to the multiple fatalities and injuries that occurred in the two Force 3 incidents. Casting had the highest injury rate in 2024, which has typically been Transfer operations in the past.**
- **As stated in the past, this lower injury frequency can be attributed at least partially to:**
    - **The increased use of primary and secondary PPE;**
    - **Improvements in PPE materials and design;**
    - **An increased focus on hands-free Casting operations that remove personnel from high-risk Casting operations; and**
    - **Possibly increased training and hazard awareness.**
- **In 2024, there were 32 Transfer explosions, all Force 1 but for one Force 2. Wet hand, furnace tools, or other equipment accounted for 14 of these incidents. Wet, rusty skim, or drain pans accounted for six Transfer incidents, including the one Force 2.**
- **The highest number of incidents occurred in Reduction plants (64), followed by Rolling (52). Recycling and Extrusion plants both had 11 incidents.**

- **There were five Reduction plant injuries, which were all Minor. Three were the result of wet tools, and two were the result of wet reduction process additions.**
- **Rolling plants had 12 injuries, and all were Minor with five being at Cast Start and four at Termination. Three other injuries occurred during a lancing operation associated with a wet floor.**
- **All three Extrusion plant injuries (2 Fatal and 1 Serious) occurred during the Force 3 Steady-State casting incident noted above, related to operator error and a high cast rate.**
- **There were 20 Recycling plant injuries (5 Fatal and 15 Minor). All but one Minor occurred from the Force 3 Steady-State casting explosion noted above due to a cable equipment failure.**
- **Over the past 10 years, three particular years: 2015, 2018, and 2024 stand out with a high number of injuries: 1) one 2015 Force 3 Melting explosion with 35 Minor injuries; 2) two 2018 Force 3 Casting explosions with 25 injuries, including eight Fatalities; and 3) 2024 with two Force 3 Casting explosions with seven Fatalities, one Serious and 15 Minor injuries.**
- **Starting with the 2023 report, new charts and data were initiated examining "by plant type" (Reduction, Rolling, Extrusion, and Recycling) incidents, injuries, and % injuries per incident for the 13 years 2012 through 2024. Differences were noted in the number of incidents as well as % injuries per incident between these four plant types. Reduction plants have the highest number of incidents compared to the others, but with moderately low injury rates. Extrusion plants have the lowest number of incidents and a low number of injuries, but with a high incident rate variability. Recycling plant incidents have increased over the past eight years with typically low injury rates, however that changed in 2024 with the Force 3 casting explosion with five fatalities and 14 Minor injuries. Rolling plant incidents increased significantly over the past ten years with injury rates higher than Reduction and Recycling. Further investigation and data analysis would seem appropriate to understand these differences, which then could possibly lead to reducing injury rates further.**

EXPLANATION & DISCUSSION OF CHARTS AND DATA:

The Aluminum Association classifies molten metal explosions according to **Force Level**, with **Force 1** being the least severe and **Force 3** being the most severe. Table 1 below provides information on the criteria used for rating **Force Level**. Figures 1 through 48, provided in the accompanying PowerPoint slides, display various charts and tables, including Table 1.

Table 1: Explosion Rating Force Criteria

Figure 1 displays by year from **1981** through **2024** the total number of reported incidents, **4834**.

Guidelines	Force 1	Force 2	Force 3
Property Damage	None	Minor	Considerable
Light	Minimal	Flash	Intense
Sound	Short cracking	Loud Report	Painful
Vibration	Short and sharp	Brief rolling	Massive structural
Metal Dispersion	<15 feet	>15 to 50 feet	>50 feet

There were **141** explosions reported in 2024, compared to **156** explosions reported in **2023.** The record high **198** was in **2022** for the 44 years of the Molten Metal Incident Reporting Program initiated in 1981. The **141** total **2024** incidents are lower than the average 161 reported incidents for the five previous years, 2019 through 2023. This was the second lowest number of incident reports in the last 10 years with **140** incidents reported in **2021**. Starting in 2016 and over the last 10 years there was a sharp increase in reported incidents compared to the previous nine years.

Figures 2 through 7 provide **Force Level** data for all years of the program, 1981 through 2024, in various formats, including the number of incidents and rates. **Figure 2** displays the reported incidents each year for all Force Levels 2. In 2024 there were **112 Force 1**, **27 Force 2,** and **2 Force 3** explosions. There were **0 Force 3** explosions in **2023** and **2022** and **one** each in **2021** and **2020**. **Figure 3** displays only **Force 2 & 3** incidents for the same time period, along with the average number of incidents over that time period: **22.8/year Force 2 and 2.9/year Force 3.**

The percentage of **Force 2** explosions compared to **Force 1** incidents has been increasing over the past 8-10 years although not at record highs compared to earlier in the program. This increase is displayed in a new chart, **Figure 4**, which provides the **percentage** of **Force 1** and **Force 2** incidents for the years **2000 through 2024**. There was a drop-off in Force 2 incidents starting in

2010 which continued through 2015. The **%** of **Force 2** incidents increased from **5.7%** in **2015** to **19.1%** in **2024**.

Figure 5 shows the reported number of **Force 3** incidents from **1981** through **2024**. From **2008** through **2024** there has been either **zero** or **one Force 3** explosion reported annually with two exceptions, **two Force 3** explosions in both **2018** and **2024**. The average number of **Force 3** explosions over the last **5** and **10** years (**0.8/yr.** and **0.9/yr.** respectively) continues to show a much lower level compared to the **2.5/yr.** average for the entire reporting history from **1981** through **2024**.

Figures 6 and 7 display a comparison of all three **Force Levels** for the entire reporting history from **1981** through **2024** in two different formats: 1) bar graph and 2) pie-chart. **Force 1** incidents account for **77.2%** of all incidents, with **20.3%** being **Force 2** and **2.5%** rated as **Force 3**.

Figures 8 through **15** provide various formats of injury incident data (**Minor, Serious, and Fatal**) for the years 1981 through 2024. In 2024, there were a total of **seven Fatalities, three Serious** injuries, and **31 Minor** injuries. These **41** injuries are the highest number since 2015 with **56**, which were all **Minor**. The last time there was a significant number of reported **Fatalities** was in 2018 with **eight**. There were a total of **1686 injuries** reported over the entire lifetime of the program. The **Figure 8** bar chart shows **Minor, Serious,** and **Fatal** injuries for each year from 1981 through 2024. The downward trend of injuries over the previous eight years was reversed in 2024 as shown by green and red arrows in **Figure 8**.

The downward injury trend reversed due to **two 2024 Force 3** explosions that occurred internationally. The incident information was sourced from government reports, and not from the typical method of company reports. These **two Force 3** explosions accounted for all **7 Fatalities** for the year, plus **1 Serious** and **14 Minor** injuries. In **2018**, all **8 Fatalities** plus **2 Serious** and **2 Minor** injuries occurred as the results of **two Force 3** incidents, also occurring internationally with information sourced through government reports.

Figure 9 displays the injury rate in terms of **% injuries per total annual incidents** from **2001** through **2024**. Green and red arrows show the decrease in injuries from **2016–2023**, followed by a sudden increase in **2024**. **Figure 10** highlights the difference between **Minor, Serious,** and **Fatal** injury rates for years **2001** through **2016**, compared to **2017** through **2023**. The injury rates for the categories **Minor** and **Serious** declined from 2001 – 2016 vs. 2017 – 2023 by **73%** and **78%** respectively. **Fatalities** declined **27%** between these two groups of years. Additionally, the **2017-2023** data include **two 2018 Force 3** explosions with **14** injuries (**eight Fatal, two Serious,** and **two Minor**). The blue bars in **Figure 10** also show the abrupt reversal in **2024** back toward the **2001 - 2015** injury rates as was noted in **Figure 9**.

From **1981** through **2024**, there are now a total of **1686 Minor, Serious,** and **Fatal** reported injuries with **Figure 11** showing the total injuries in these three categories. The **Figure 12** pie chart breaks this down into percentages: **70.6% Minor**, **23.1% Serious,** and **6.3% Fatal**.

Figure 13 presents the likelihood of no injury per hundred incidents versus the likelihood of an injury in each injury category. This indicates that for every hundred incidents reported there is a **24.6%** rate for **Minor** injuries, an **8.1%** rate for **Serious** injuries, and a **2.2%** rate of **Fatalities** versus a **65.1%** rate of **No Injury**. The likelihood of a **No Injury** increased from **64.9**% in **2023** to **65.1**% with the **2024** data. Since explosions are typically more likely to be reported when there is an injury of some degree, these numbers are certainly inflated compared to the actual data if all

explosions were reported. However, this does provide an indication of the potential rate of an injury per incident.

Figure 14 displays data only related to **Fatalities** for the entire reporting program from **1981** through **2024**. There have been **15 Fatalities** over the past 10 years, with **eight** reported in **2018** and **seven** in **2024**. As indicated above, these were all the result of **Force 3** international explosions, with information sourced via government reports. The **1.5/yr.** average **Fatal** rate for the past ten years is significantly lower than the **2.3/yr.** annual rate for the entire length of the program.

Figures 15 through **48** provide more detailed information regarding the **141** reported explosions in **2024** along with similar charts comparing this year's data with the entire database from 1980 through 2024. Additionally, there are newer charts, first presented in the 2020 report, which provide additional insight into: 1) Recent trends in reported explosions and injury rates for **Melting, Casting,** and **Transfer** operations (**Figures 17-22**); and 2) Summaries of the major causes of **Casting** and **Transfer** incidents over recent years (**Figures 28, 29, 32, and 33**).

Figure 15 shows the 2024 data by Force Level for each of the four major categories of operations: **Melting, Casting, Transfer, and Other**. This can be compared to the same data for the years **1980** through **2024** in **Figure 16**. In **2024**, most explosions occurred in **Casting (71)**, with **Melting (29)**, **Transfer (32),** and **Other (9)** being the lowest as in the past. **Casting** accounted for highest number of **Force 2** incidents (**15**) as well as the **two Force 3** explosions. **Melting** had **10 Force 2** incidents and **Transfer** and **Other** each had **one Force 2**.

Eight of the **nine Other** incidents occurred in the **Reduction** Process, with one occurring in **Rolling**. The incidents that occurred in the Reduction process were all **Force 1** and involved wet equipment, wet pot additions, and a tap-out on a wet floor. **Two Minor** injuries resulted from these **eight Force 1** incidents. The **Other Rolling** incident was a **Force 2** explosion with **three Minor** injuries. The explosion occurred during a lancing procedure with molten aluminum falling into water in a pit below the operation. This type of explosion, although somewhat unusual compared to other molten aluminum explosions, has been noted in previous years. Reviewing the database, this was the first one rated a **Force 2**.

Figure 16, showing data from 1980 through 2024, was modified last year and now includes the % of **Force 1, 2, and 3** incidents for each of the four operations discussed above. Notable is the relatively high percentage of **Melting Force 3** incidents, which is **5%** of all **Melting** incidents. This is compared to the other three operations that are each at **1-2%** for **Force 3** incidents. Also of note is that **Melting Force 2** incidents have a high percentage at **27%**; while both Casting and Transfer have the same high percentage of **18% Force 2** explosions.

Figures 17 through **22** provide **injury** and **incident** data for each **Melting**, **Casting,** and **Transfer** operations in two different formats: 1) **Injuries** and **Incidents**; and 2) **Injuries** per **Incident** or **Injury Rate**. Data is displayed by year from **1990** through **2023**, excluding **2011**. Unfortunately, the data is not available for program year 2011 and years prior to 1990.

In general, the data shows an upswing in incidents in the early 2000's and a higher incident volume for the last 8-10 years in all three operation categories. However, the injury rates per incident are much different comparing the three operation categories to each other.

The **Melting Injury Rate** has been very low for the last 15 years (< 0.05), except for 2015 (>0.7), which had **35 Minor** injuries resulting from one **Force 3** explosion when a furnace bled out into a casting pit. The **Injury Rates** for **Casting** and **Transfer** (**Figures 20** and **22**) are much higher than for **Melting** (**Figure 18**), on the order **10X** higher for **Casting** and **20X** higher for **Transfer**.

The general **Injury Rate** trends over the last 35 years have certainly been downward, but the data is scattered as evidenced by exceptionally low R^2 values shown in the three **Injuries** per **Incident** graphs (**Figures 18, 20,** and **22**). In **2024** with the two **Force 3 Casting** explosions reported and the multiple **Fatal, Serious, and Minor** injuries associated with them there is a significant increase in the **Casting Injury Rate** in **2024**. The **Transfer Injury Rate** has been trending downward especially in the last 12 years.

There are probably numerous reasons for the general long downward trend in the **Injury Rate** including: 1) improvements with primary and secondary PPE materials, design, and use; 2) movement toward 'hands-free' casting removing personnel from the Casting pit during cast starts; and 3) increased training and hazard awareness.

Figure 23 provides **2024 data** regarding the type of charge materials involved in the **29 Melting** incidents**, 0 Force 3, 10 Force 2, and 19 Force 1**. In **2024**, only **29** Melting explosions were reported—the lowest yearly count since 2013, when there were 27. For the years **2014** through **2023**, there were an average of **53 Melting** incidents. As typical of the past, the large majority of the **2024 Melting** incidents involved scrap charging, **19** of the **29** explosions; **8** being **Force 2**. Alloying materials being the second highest with **five**, with **one Force 2**.

The 2024 data for Melting incidents is in line with the compilation of the **Melting** explosion data shown in **Figure 24**. This chart provides the type of charging materials involved with the **Melting** incidents for the years **1980** through **2024**. Wet or contaminated scrap is the reason for most of the **Melting** explosions. The second highest reason is wet alloying materials. By a high margin, most of the **Force 2** and **Force 3 Melting** explosions have been related to **Scrap** charging. After **Scrap**, the next leading cause of **Force 2** and **Force 3** explosions occurred when charging various types of sows (primary and RSI) and T-bar.

Figure 25 provides a breakdown of the **71 Casting** incidents in **2024** in two separate ways: by stage in the process and by type of **Casting** process. As typically seen in the past, most of the explosions occurred during the **Start- up (51)**, including **eight Force 2,** and **0 Force 3**. **Steady-state** had the fewest number of incidents, **five**, which is also typical, however **two** of these were **Force 3,** along with **two Force 1**. Both **Force 3** explosions occurred overseas, and government reports provided incident information. These two Force 3 incidents both occurred during billet **Steady-state** casting. Of these two incidents, there were a total of **seven Fatalities**, **one Serious** injury and **14 Minor** injuries. One of the incidents occurred at a casting pit employing a system where the starting block base is lowered and raised using a cable system. The cable wire failed during **Steady-state** casting resulting in a massive bleedout and explosion. The other **Steady-state** incident occurred due to a massive bleedout occurring due to an excessive cast rate because of operator error. Additionally, there were **17** occurring during casting **Termination**, with **10 Force 1** and **7 Force 2**.

Figure25 also breaks down the **71** incidents by casting product type: 41 DC **billet** or **slab (27 Force 1, 12 Force 2, 2 Force 3)**, **18 sow** or **mold** casting **(25 Force 1, 3 Force 2)**, and **2 Force 1 roll** casting.

Figure 26 shows **DC Casting** incidents by drop segment for years **1980** through **2024**. The historical data is similar to the 2024 data shown in **Figure 25** in that most explosions occur during **Start-up**. Starting in **2021**, the total **End-of-Cast** explosions outnumber the total **Steady-state** explosions**.**

For **2024**, **Figure 27** provides the major causes of the **71 Casting** incidents. They are organized by cast stage for **VDC** casting and by **mold** or **sow** casting. For DC **Casting**, the main **Start-up** issues were related to wet starting blocks, wet equipment or launders and butt curl-bleed-outs. The **Steady-State** issues were equipment failure and operator error. The main **DC** casting **Termination** issues were wet/rusty drain pans, wet hand tools and ingot head under water. For **Strip/Roll** casting the main issue was **Start-up** wet or unoiled drain pans. The main **sow** and **mold** casting incidents were due to wet, unpreheated and cracked molds and wet hand tools.

Figures 28 and **29 are relatively** new charts, started in 2021, that provide additional analysis of the primary causes of **Casting** explosions. Showing data from **2015** through 2024, **Figure 28** provides the major causes for all Force Levels, while **Figure 29** is data for only **Force 2** and **3 Casting** explosions. By a large margin, the largest number occur during **sow** or **mold** casting due to wet, cracked or rusty molds (**258**), compared to the next highest, **VDC Cast-start** explosions due to excessive curl, hang-ups and bleed-outs (**69**). When only **Force 2** or Force 3 explosions are considered, **Figure 29**, the highest number of explosions (**22**) are due to wet and rusty drain pans at **Termination** and aborts. These are followed by **VDC Cast-start** explosions resulting from excessive curl, hang-ups and bleed-outs (**19**), **sow** and **mold** casting with wet/cracked/rusty molds **(13),** and **DC Cast Start** due to wet/rusty bottom blocks (**11**).

There were **32 Transfer** explosions (**31 Force 1** and **1 Force 2**) in **2024**, as shown in **Figure 14**. The reasons for these explosions are provided in **Figure 30**. Wet hand, furnace tools, or other equipment accounted for **14** of these incidents. Wet, rusty skim or drain pans accounted for **six Transfer** incidents, including the **1 Force 2**. There were also **four** incidents due to wet launder refractory, **four** for wet sampling molds and **two** for metal on a wet floor.

Figure 31 provides a bar chart showing the equipment involved in the **938 Transfer** explosions for the years **1980** through **2024**. The highest number of **Transfer** explosions are related to **Drain Pans**, followed by **Trough** and then **Other**.

Like **Figures 28 and 29** presented above for **Casting**, **Figures 32 and 33** were first presented in **2021**, displaying further detail of the major causes of **Transfer** explosions. **Figure 32** provides the data regarding the major causes of all **Transfer** explosions for the years **2008** through **2023** (excluding 2011), while **Figure 33** provides this information for only **Force 2** and **3** explosions. **Figure 31** indicates that the highest number of **Transfer** incidents are related to wet/rusty drain pans (**154**) followed by wet tools (**144**). Wet/rusty drain pans is the leading cause of **Force 2** and **3** explosions (**19**) with wet refractory or equipment second (**9**).

When combining **Casting** and **Transfer 2024** incident data for wet/rusty drain pans, this category of explosions accounts for **18%** (19 of 103) of all the explosions in these two operations. In **2022 and 2023**, it was **20%**.

In **2024** there were **41** injuries resulting from the **141** explosions. **Figure 34** shows the **23 Minor**, **three Serious** and **seven Fatal** Injuries by **Operation** (**Melting, Casting, Transfer and Other**). Casting accounted for **33** of the injuries. As noted above, the **two Force 3 Casting** incidents

accounted for the **7 Fatal** plus **1 Serious** and **14 Minor** injuries. **Three Minor** injuries occurred in **Transfer** and **five** in **Other**.

Figure 35 provides **Injury by Operation** data for 1980 through 2024. The highest number of **Minor** and **Serious** injuries have occurred in **Casting** operations. **Melting** operations account for the highest number of **Fatalities,** as well as the highest number of **Force 3** explosions as seen In **Figure 16**. As indicated in the past, a considerable number of injuries have occurred in relatively straightforward **Transfer** operations, including **82 Serious** and **seven Fatalities.** Of note in **2024,** there were **zero Serious** and **0 Fatal injuries** reported in **Transfer** operations**.**

Figures 36 and 37 provide incident data versus the type of **Process Plant** (**Reduction, Extrusion, Rolling,** and **Recycling**) for **2024** and for **1980** through **2024** respectively. In **2024**, the highest number of incidents occurred in **Reduction** operations (**64**), compared to the next highest in **Rolling** operations (**52**). The **two Force 3** explosions discussed above occurred, one each in **Extrusion** and **Recycling**. **Rolling** and **Recycling** had the highest number of **Force 2** incidents, **14** and **7** respectively. **Reduction** reported **four Force 2** explosions and **Extrusion two**. For the entire reporting period, **1980** through **2024**, the highest number of incidents have occurred in **Reduction,** and the second highest were in **Rolling**, which by far has reported highest number of **Force 3** explosions.

The main causes of the **64 Reduction** facility explosions in **2024** are presented in **Figures 38** and **39.** They are listed by **Melting**, **Casting**, **Transfer** and **Reduction** incidents. **Melting** incidents were related to wet charging materials (scrap and alloy). Most incidents at the **Reduction** facilities took place during **Casting**, mainly involving sow or mold casting. The primary reason in sow **Casting** was for cracked, wet or rusty molds. Most start-up **VDC** casting incidents were the result of wet equipment or hand tools. **Transfer** incidents were primarily related to wet hand tools, wet sampler molds and wet refractory, transfer troughs. **Reduction** cell incidents were primarily the result of wet anodes, wet pit additions and wet wood.

Figure 40 provides the main causes for **12 Recycling** incidents in **2024**. Of note, **7** of the **12** incidents were higher than **Force 1**. Of the **five Casting**, **one** was **Force 3** and **four** were **Force 2**. The **Force 3** billet casting incident was reviewed above and was the result of a cable failure, during **Steady-state** casting. **Two** of the **Force 2 Casting** incidents occurred from **Start-up** bleed outs. The other **two** were during **Termination**, the result of a wet tool and molten on a wet ingot head. The **two Force 2 Melting** incidents were the result of wet scrap.

Figures 41 through **44** bar charts provide information regarding injuries recorded for the four plant types: **Reduction, Rolling, Extrusion** and **Recycling**.

For **Reduction, Figure 41,** in **2024** there were only **5 Minor** injuries, compared to **10 Minor** and **1 Serious** injury in **2023**. **Three** injuries occurred during metal **Transfer** operations due to wet tools and **two** occurred in the **Reduction** process as the result of wet additions.

There were **12** injuries in **Rolling**, all **Minor**, shown in **Figure 42**, a significant increase compared to the **two Minor** injuries reported in **2023**. Nine injuries occurred in **Casting** with **five** during **Start-up** and **four** at **Termination**. Of note, **three Start-up** incidents were the result of a wet drain pan and **two** of the **Termination** incidents were also the result of a wet drain pan. There were also three **Minor** injuries that occurred during a lancing operation with molten falling onto a wet floor.

For **Extrusion** in 2024**, Figure 43**, there were **three** injuries (**two Fatal** and **one Serious**), all related to the **Steady-State** casting **Force 3** massive bleedout and explosion discussed above that was the result of operator error casting at an excessive cast rate. No other injuries were reported in **nine** other **Force 1** and **two Force 2 Extrusion** plant incidents. In **2023** there were also **three** reported **Extrusion** plant injures, all **Minor**.

In **2024**, **Recycling**, **Figure 44**, accounted for **5 Fatal** and **15 Minor** injuries. All **Fatal** and the **14 Minor** injuries were the result of the **Steady-State** casting **Force 3** explosion discussed above. A massive bleedout and subsequent explosion occurred due to cable failure of the equipment that lowered and raised the bottom blocks**.**

Figure 45 summarizes the **2024** injury data by type of **Process Plant** and **Figure 46** provides this same data for **1980** through **2024**. In **2024,** the highest number of injuries (**15**) occurred in **Recycling**, and this was due to **one Force 3** casting incident discussed above. **Reduction** had only **five Minor** injuries in **2024**, and the second lowest of the four plant type categories. This contrasts with what is shown in **Figure 46** where, for **1980** through **2024** data, **Reduction** plants have the highest number of total injuries by a considerable margin compared to the other three plants types.

Starting with **2023** incidents there were four new charts introduced, **Figures 47 and 48**, which provide further incident and injury data analysis of the four **Process Plants** (**Reduction, Extrusion, Rolling,** and **Recycling**). These charts provide incident, injury, and injuries per incident rates for these four plant categories for the past 13 years (**2012** through **2024**). Severity of injury (**Minor, Serious,** and **Fatal**) was not investigated separately in this analysis.

Figures 47 and **48** show that there is a significantly higher number of **Reduction** plant incidents compared to the other three plant types. However, starting in **2016** there was a large drop in the number of **Reduction** plant injuries and subsequently the incident per injury rate. Both the number of injuries and injury rate have remained below **2016** and prior values through **2024**. **Recycling** plant incident reporting increased significantly starting in **2017** through **2023** from approximately **5 per year** to an average of **35 per year**. Along with the higher number of reported injuries during these seven years, the injury rate variability varied between **0%** to **5%**, which was the lowest of the four plant types in this time frame. In **2024,** this trend reversed for **Recycling** with lower reported incidents (**12**), but with a much higher number of injuries (**20**). Subsequently, there is an extremely high **injury rate (167%)** in **20224.** This was the result of the one **Force 3 Casting** incident discussed above with **5 Fatal** and **14 Minor** injuries.

Figure 48 displays that the number of reported **Rolling** plants incidents is approximately 3-4X higher compared to **Extrusion** plants. The **Extrusion** injury rate is often the highest of the four plant types and is extremely variable, ranging from 0% to 87%. This may be related to the very low number of **Extrusion** incidents that are reported compared to the other three plant types. However, in 2024, the **Recycling** plant injury rate was the highest of the four plant types at **167%**, as discussed above. The **2024 Rolling** plant injury rate was very high, **23%**, and similar to the **Extrusion** plant rate of **25%**. All the **15 Rolling** plant injuries in **2024** were **Minor**. The **2024 Rolling** plant injury rate was the highest in the last 10 years, only being surpassed in **2014** at **36%**.

The newer plant incident and injury data indicates that further investigation, analysis, and discussion should be pursued to determine why typically higher injury rates are observed in **Rolling** and **Extrusion** compared to **Reduction** and **Recycling.** A possible explanation may be

the higher application of the billet and slab **VDC Casting** processes in **Rolling** and **Extrusion** compared to **Reduction** and **Recycling**. Additional understanding could lead to reducing injury rates.

The Aluminum Association Molten Metal Incident Report Form for use in reporting incidents can be found at: https://www.aluminum.org/health-safety

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