

ANNUAL SUMMARY REPORT ON MOLTEN METAL INCIDENTS IN 2022

September 2023

For the year **2022**, **198** molten metal incident reports occurring world-wide were received as compared to **140** reports for **2021** and **147** reports for **2020**. The attached figures summarize the reports for 2022 as well as the data for the years 1980 through 2022.

SUMMARY POINTS:

- For **2022**, there were **198** explosion incidents reported. This not only reversed the downward trend in reported incidents over the previous five years but was also the highest number of incidents ever reported in the 42 years of the Molten Metal Incident Reporting Program initiated in 1981. The previous high was 195 in 2016.
- There were 175 Force 1 explosions, 23 Force 2 explosions and zero Force 3 explosions reported in 2022. Compared to 2021, Force 2 explosions were the same, while the Force 1 explosions increased significantly from 116 to 175. 2022 was the first year since 2017 with no Force 3 incidents reported. There was one reported in each of the last three years and two in 2018.
- The notable increase in Force 2 explosions that started in 2016 with an average of 21/yr. continued into 2022. This reversed a downward trend that was observed starting around 2008 and continued through 2014. However, when considering the record number of reported incidents, there was not a corresponding increase in Force 2 explosions, as may be expected.
- Of significant note, there were again no reported Fatalities in 2022, same as for the years 2015 through 2017 and 2019 through 2021. There have been 99 reported Fatalities for the entire length of the program.
- Also of note, there were no Serious injuries reported in 2022, only 13 Minor injuries from the record high of 198 incidents. This was the same injury rate per incident of 7% as was observed in 2021, with 10 injuries for 140 incidents.
- Since 2013 there have been only Minor injuries reported (zero Serious and zero Fatal) in three other years: 2013 (23 Minor), 2015 (56 Minor) and 2020 (7 Minor).
- Over the past ten years there were only two years with Fatalities: 2014 with one and 2018 with eight, which involved two major Casting incidents. The 0.9/yr. average Fatality rate for the past ten years is significantly lower than the 2.4 annual rate for the entire length of the program.

- In 2022, there were no injuries reported for Melting, which was the same in 2021. Over the past five years there have been only three Melting injuries (two Minor and one Serious).
- Three injuries occurred during Transfer operations and ten during Casting. Five of the ten Casting injuries occurred during VDC Casting Start-up.
- Reduction and Rolling operations each reported six Minor injuries, while one was reported from Extrusion and zero from Recycling. This is the second year in a row with Extrusion reporting only one Minor injury.
- As noted in recent annual incident reports, the sharp decrease in injuries starting in 2016 compared to historical values has continued through 2022. When comparing the average amount of injuries/year for the years 2001-2015 vs. 2016-2022, the latter time frame is significantly lower (13.9 vs. 48.1 injuries/yr.) for all categories: Minor, Serious, and Fatal. For these last seven years, the average Fatal/Yr. was 52% lower, the average Serious/Yr. was 71% lower, the average Minor/Yr. was 73% lower, and the average Total Injuries/Yr. was 71% lower.
- The injury rate per incident has been trending downward over the past 5-10 years for all three operations, Melting, Casting and Transfer, which was observed in the new charts added to the 2020 report. This metric has been very low (close to or at zero), especially for Melting, except for one year, 2015, when a major furnace bleed-out and Force 3 explosion occurred resulting in numerous Minor injuries.
- As stated in the past, this lower injury frequency can be attributed at least partially to 1) the increased use of primary and secondary PPE; 2) improvements in PPE materials and design; 3) an increased focus on hands-free Casting operations that remove personnel from high-risk Casting operations; and 4) possibly increased training and hazard awareness.
- As often in the past, 93 Casting incidents accounted for the highest number of explosions (84 Force 1 and 9 Force 2). Most explosions, 65, occurred during start-up, which included seven of the nine Force 2 explosions. Sow or mold Casting accounted for 47 incidents and there were 42 incidents during VDC slab and billet Casting.
- For Casting explosions starting in 2015 through 2022, by a factor of 4X, the highest number occur during sow or mold Casting due to wet, cracked or rusty molds. This compares to the next highest for VDC cast start explosions due to excessive curl, hang-ups and bleed-outs. When only Force 2 or Force 3 explosions are considered, then VDC cast start, for these same reasons, has the highest number (16) with VDC termination explosions due to wet and rusty drain pans being the next highest (14).
- Force 2 and 3 Transfer incident data from 2008 through 2022 indicate that wet/rusty drain pans account for 60% of all the explosions.

- For 2022, 23 of 115 (20%) Casting and Transfer explosions were related to wet/rusty drain pans.
- There were 74 Melting explosions, including nine Force 2 explosions. All but one of these nine Force 2 explosions were related to wet/contaminated scrap, sow or RSI.
- There were two Minor injuries reported from the 22 Transfer incidents. Wet hand and furnace tools or wet equipment were involved in 13 of the explosions and six involved wet/rusty drain or skim pans.
- Force 2 and 3 Transfer incident data from 2008 through 2022 indicate that wet/rusty drain pans account for 60% of all the explosions.
- 2015 and 2018 are two years in the past ten that stand out with a high number of injuries: 1) one 2015 Force 3 Melting explosion with 35 Minor injuries; and 2) two 2018 Force 3 Casting explosions with 25 injuries, including eight Fatalities.
- New “by plant type” (Reduction, Rolling, Extrusion and Recycling) data analysis of incidents, injuries and % injuries per incident for the past 11 years provided new statistics and charts, which indicate differences in the number of incidents and % injuries per incident between these four plant categories. Reduction plants have the highest number of incidents compared to the others, but with low injury rates. Additionally, the Rolling and Extrusion plants have approximately 2X higher rates of injuries per incident compared to Reduction and Recycling over the past seven years. Further investigation and data analysis would seem appropriate to understand these differences, which then could possibly lead to reducing injury rates further.
- New analysis and charts that were added last year were continued this year which display incidents per month for the three categories of Melting, Casting and Transfer. The additional year of data supported the previous results showing a higher Melting incident rate in the northern hemisphere for January through March, most likely related to the higher potential for charging materials to be contaminated with water, snow and ice. Very low Melting incidents in December continued with no correlation to similar results in Casting or Transfer.

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 50, provided after the discussion below, display various charts and tables, including Table 1.

Table 1: Explosion Rating Force Criteria



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

Figure 1 displays by year from **1981** through **2022** the total number of reported incidents, **4537**. There was a record number of **198** explosions reported in **2022**, compared to **140** in **2021**. The highest previous record was **195** in **2016**. Additionally, 2022 reversed the downward trend of reports over the last 5 years.

Figures 2 through 6 provide **Force Level** data for all years of the program, 1981 through 2022, in various formats, including the number of incidents and rates. **Figure 2** displays the reported incidents each year for all three Force Levels. **Figure 3** displays the same data but broken down by **Force Levels 1, 2 and 3** for each year. In 2022 there were **175 Force 1**, **23 Force 2** and **zero Force 3** explosions. Compared to **2021**, **Force 2** explosions were the same, **23**, while the **Force 1** explosions increased from **116** to **175**. There were **two Force 3** incidents in 2018 and **one Force 3** explosion in each year from **2019 through 2021**.

From **2008 through 2022** there has been either **zero** or **one Force 3** explosion reported annually with one exception in 2018 when **two Force 3** explosions were reported. The average number of **Force 3** explosions over the last **five** and **ten** years (**1.0/yr.** and **0.8/yr.** respectively) continues to show a much lower level compared to the **2.9/yr.** average for the entire reporting history from **1981 through 2022**. The notable downward trend of **Force 2** explosions observed in **Figure 3**, starting around 2008 and continuing through 2014, was reversed beginning in 2016 and has continued through 2022 with an average of **21/yr.** over the past **seven** years.

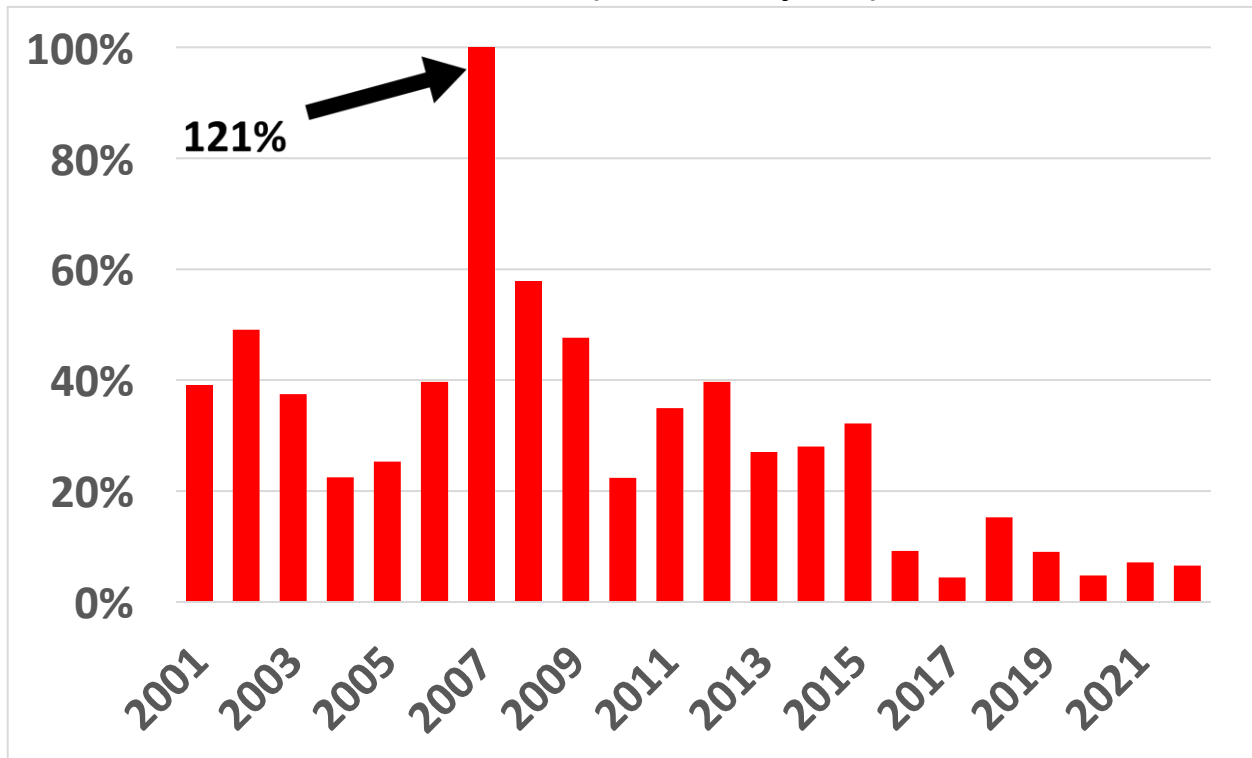
Figures 5 and 6 display a comparison of all three **Force Levels** for the entire reporting history from 1981 through 2022 in two different formats: 1) bar graph and 2) pie-chart. **Force 1** incidents account for **76.8%** of all incidents, which has been increasing slightly for the last four years since 2019 which was at **75.6%**. The **Force 2** and **Force 3** incident rate in 2022 both lowered slightly compared to 2021 from **20.9%** to **20.5%** and from **2.8%** to **2.7%** respectively.

Figures 7 through 13 provide various formats of injury incident data (**Minor, Serious and Fatal**) for the years 1981 through 2022. There were a total of **1628 injuries** reported over the entire lifetime of the program. The **Figure 7** bar chart shows **Minor, Serious and Fatal** injuries for each year. In 2022 there were a total of **13 injuries**, all **Minor**. Since 2013 there have been only **Minor** injuries reported (**zero Serious** and **zero Fatal**) in three other years: 2013 (**23 Minor**), 2015 (**56 Minor**) and 2020 (**7 Minor**).

There have been **99** reported **Fatalities** for the entire length of the program, starting in 1981. Over the past ten years there were only two years with **Fatalities**: 2014 with **one** and 2018 with **eight**, which involved two **Force 3 Casting** incidents. The **0.9/yr.** average **Fatality** rate for the past ten years is significantly lower than the **2.4/yr.** annual rate for the entire length of the program.

Of high significance, in **Figure 7** a green arrow indicates a sharp decrease in total injuries starting in 2016 compared to historical values. The reduction in injuries over the past seven years is displayed more clearly in **Figures 8 and 9**. Both charts present data from 2001 through 2022. **Figure 8** is a new chart and is also shown below (**Chart 1**). The chart displays **% Injuries per total annual incidents** and clearly shows the rate of injuries per incidents reported declining starting in 2016. **Figure 9** was started three years ago for the 2020 summary report. When comparing average injuries/yr. for the years 2001-2015 versus 2016-2022, the latter time frame is significantly lower for all categories of injury: **Minor, Serious and Fatal**. For these last seven years, the average Fatal/Yr. was 52% lower, the average Serious/Yr. was 71% lower, the average Minor/Yr. was 73% lower and the average Total Injuries/Yr. was 71% lower. Additionally, this data includes the two 2018 **Force 3** explosions with **12** injuries (**8 Fatalities, 2 Serious and 2 Minor**).

Chart 1
% Injuries per Total Annual Incidents
2001 to 2022 (Total 856 Injuries)



From 1981 through 2022, there are now a total of **1628 Minor, Serious and Fatal** reported injuries with **Figure 10** showing the total injuries in these three categories. The **Figure 11** pie chart breaks this down into percentages: **70.3% Minor, 23.6% Serious** and **6.1% Fatal**.

Figure 12 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 **25.2%** rate for **Minor** injuries, an **8.5%** rate for **Serious** injuries and a **2.2%** rate of **Fatalities** versus a **64.1%** rate of **No Injury**. All three of these injury rates decreased in 2022 versus 2021 percentages. 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 13 displays data only related to **Fatalities** for the entire reporting program from 1981 through 2022. There have been **nine Fatalities** over the past 10 years, with eight of the ten reported in 2018, as previously noted, due to the **two Force 3 Casting** explosions. The **0.9/yr.**

average Fatality rate for the **past ten years** is significantly lower than the **2.36/yr.** annual rate for the entire length of the program.

Figures 14 through 48 provide more detailed information regarding the **198** reported explosions in **2022** along with similar charts comparing this year's data with the entire database from 1980 through 2022. 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 16-21**); and 2) Summaries of the major causes of **Casting and Transfer** incidents over recent years (**Figures 27, 28, 31 and 32**).

Figure 14 shows the 2022 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 2022 in **Figure 15**. In 2022, most explosions occurred in **Casting (93)**, with **Melting (74)**, **Transfer (23)** and **Other (8)** being the lowest as in the past. All **Other** explosions occurred in the **Reduction** Process. There was almost an equal number of **Force 2** explosions for **Casting (10)** compared to **Melting (9)**. **Transfer** and **Other** each had two **Force 2** incidents. Most **Force 2** and **Force 3** explosions for the entire reporting period continue to be related to **Melting** operations by a wide margin as shown in **Figure 14**.

As reported in previous years and shown and discussed above, when reviewing **Figures 7 through 9**, there is a general decrease in the number of injuries, especially when comparing the last seven years to the previous 15 years. **Figures 16 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 2021, excluding 2011. Unfortunately, the data is not available for program years prior to 1990 and 2011.

In general, the data shows an upswing in incidents in the early 2000's and a higher incident volume for the last eight years. In contrast, however, there appears to be a downward trend in **Injuries per Incident or Injury Rate** over the last seven to ten years. **Melting Injuries and Injury Rate (Figures 16 and 17)** have been very low for the last ten 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. For **Casting and Transfer** operations, the **Injury Rate** has been very low but variable over this time period (**Figures 19 and 21**).

For the **Injury per Incident Rate** charts (**Figures 17, 19 and 21**) a best fit line is provided along with R^2 values, which are very low due to data scatter. It is a positive sign that the **Injury Rate** is trending in this direction over the past several years. There are probably numerous reasons for this trend 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 22 provides 2022 data regarding the type of charge materials involved in the **74 Melting** incidents. The leading cause of the explosions (**66** of the **74**) was wet scrap, sows, RSI or T-Bar. **Eight of the nine total Force 2 Melting** explosions occurred in these **66** incidents. Wet alloy material (Mg) accounted for **four Force 1** explosions.

A compilation of the **Melting** explosion data over the years 1980 through 2022 for the various types of charging materials involved is shown in **Figure 23**. Wet or contaminated scrap continues to be the reason for most of the **Melting** explosions. The second highest area is related to 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 24 provides a breakdown of the **93 Casting** incidents in 2022 in two different ways: by stage in the process and by type of Casting process. There were **nine Force 2** and **zero Force 3** explosions in 2022. As typically seen in the past, most of the explosions occurred during the **Start-up (65)**, with **seven** being **Force 2**. At cast **Termination** there were **19** explosions, with **two** of the **17** being **Force 2**. There were **nine Steady-State** incidents, all **Force 1**. Most of the **Casting** explosions (**47**) occurred during the Casting of sow or mold Casting, with **two** being **Force 2**. Slightly less, (**42**) incidents, occurred with **VDC Slab** and **Billet Casting**, but this Casting category accounted for **seven** of the **nine Force 2** explosions. There were **five strip/coil Casting** incidents, all **Force 1**.

Figure 25 shows **DC Casting** incidents by drop segment for years 1980 through 2022. The historical data is similar to the 2022 data shown in **Figure 24** in that most explosions occur during **Start-up**. Starting in 2021, the total **End-of Cast** explosions outnumber the total **Steady-state** explosions.

For 2022, **Figure 26** provides the major causes of the **93 Casting** incidents. They are listed by cast stage for **DC Casting** and for mold or sow **Casting**. For **DC Casting**, the main start-up issues were related to wet starting blocks, wet equipment or launders, butt-curl, hang-ups, bleed-overs, and equipment failures. The main **DC Casting** termination issues were wet/rusty drain pans, ingot head under water and metal on the floor. The main sow and mold **Casting** incidents were due to wet or cracked molds, wet refractory and wet equipment or tools. Wet/rusty drain pans were the main reason for **Termination** issues for strip/coil **Casting**.

Figures 27 and 28 were new charts started in 2021 that provide additional analysis of the primary causes of **Casting** explosions, looking at the last eight years of data, **2015 through 2022**. **Figure 27** shows the major causes for all Force Levels, while **Figure 28** is data for only **Force 2 and 3 Casting** explosions. By a factor of 4X, the highest number occur during sow or mold Casting due to wet, cracked or rusty molds compared to the next highest, VDC **Cast Start** explosions due to excessive curl, hang-ups and bleed-outs. When only **Force 2 or Force 3** explosions are considered, **Figure 28**, then VDC **Start**, for these same reasons, has the highest number (**16**) with VDC **Termination** explosions due to wet and rusty drain pans being the next highest (**14**). These are followed by DC **Cast Start** due to wet/rusty bottom blocks (**9**) and sow and mold Casting with wet/cracked/rusty molds (**8**).

There were **23 Transfer** explosions (**21 Force 1 and 2 Force 2**) in 2022, as shown in **Figure 14**. The reasons for these explosions are provided in **Figure 29** with wet hand, furnace tools or other equipment accounting for **13** of these incidents. Nine incidents were the result of wet/rusty skim or drain pans.

Figure 30 provides a bar chart showing the equipment involved in the **884 Transfer** explosions for the years 1980 through 2022. The highest number of **Transfer** explosions are related to **Drain Pans**, followed by **Trough** and then **Other**.

Like **Figures 27 and 28** presented above for **Casting**, **Figures 31 and 32** were first presented in 2021, providing further detail regarding the major causes of **Transfer** explosions. **Figure 31** provides the data regarding the major causes of all **Transfer** explosions for the years **2008 through 2022** (excluding 2011), while **Figure 32** 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 (**134**) followed by wet tools (**116**). Wet/rusty drain pans are the leading cause of **Force 2 and 3** explosions (**15**) with wet refractory or equipment second (**6**).

When combining **Casting** and **Transfer 2022** incident data for wet/rusty drain pans, this source of explosions accounts for **20%** (23 of 115) of all the explosions.

Injuries by Operation (Melting, Casting, Transfer and Other) resulting from the **198** explosions in **2022** is provided in **Figure 33** showing that there were **13** injuries, all **Minor**. **Casting** accounted for **ten** and **three** occurred in **Transfer**. There were **zero Melting** injuries in **2022**, which was the same in **2021**. Over the past five years there have been only **three Melting** injuries (**2 Minor and 1 Serious**).

Figure 34 provides **Injury by Operation** data for 1980 through 2022. 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 15**. It should be noted that a significant number of injuries have occurred in relatively straightforward **Transfer** operations, including **81 Serious** and **seven Fatalities**.

As noted above, the highest number of **Fatalities** and **Force 3** explosions occur during **Melting** operations. Presented initially in the report last year was new data analysis investigating if there was a correlation between the “time of year” vs. the number of incidents. **Figure 35** provides this **Melting** incident data for the last six years (2017 through 2022). All causes of **Melting** incidents were part of the analysis, which primarily included wet or contaminated charge materials and wet equipment and tools.

The additional 2022 data continued to support the analysis presented last year that showed higher explosion rates in some of the “winter months”, especially February and March and to a lesser extent in January. This result would be expected since at this time of the year in the northern hemisphere, where most of the incident reports originate, there is a higher potential for winter weather of snow, ice, and rain to contaminate scrap and sows. The data, however, continued to show a low number of incidents in November and especially December, which may not be anticipated. The very low December incidents may be explained by more maintenance and holiday shutdowns/slowdowns occurring.

This data may be worthwhile sharing with plant personnel to emphasize the need for increased emphasis and attention to storage, drying and charging procedures especially during the months of January through March, which may have relaxed during the summer months.

Incident frequency by month is also provided in **Figures 36 and 37** for **Casting** and **Transfer** in the same format to evaluate if there is a similar correlation to time of year for explosions occurring in these process categories. Correlation to “winter months” or any other time of the year is not evident with this data. Also, December does not show the same lower frequency as was observed in the **Melting** data. Conversely, for **Transfer**, the highest number of incidents occur in December. The lowest **Transfer** incidents occur in May through July, which cannot be easily explained with this being a high vacation time of year. For **Casting**, the lowest number of incidents occur in February with the highest months being September and November.

It should be noted that the incident database used for these charts does not include month of the year data for all reported incidents, since not all reports contain this information. “Month of the Incident” is a requested item on the Aluminum Association Incident Report form, but it is not necessarily provided, especially when the incident data is provided via spreadsheet format by some companies.

Figures 38 and 39 provide incident data versus the type of **Process Plant (Reduction, Extrusion, Rolling and Recycling)** for 2022 and for 1980 through 2022 respectively.

In 2022, the highest number of incidents occurred in **Reduction** operations (**78**), compared to the next highest in **Recycling** operations (**49**). **Extrusion** and **Rolling** each reported **seven Force 2** explosions, followed by **Recycling** (**5**) and **Reduction** (**4**). For the entire reporting period, 1980 through 2022, the highest number of incidents have occurred in **Reduction** and the second highest are in **Rolling**, which by far has reported highest number of **Force 3** explosions.

The main causes of the 79 **Reduction** facility explosions in 2022 are presented in **Figures 40** and **41**. They are listed by **Melting, Casting, Transfer** and **Reduction** incidents. **Melting** incidents were related to wet tools and wet charging materials, scrap, RSI and Mg. Most of the **Reduction** facility incidents occurred during **Casting**, primarily sow or mold **Casting**. The primary reason in sow **Casting** was for cracked, wet or rusty molds. Start-up VDC **Casting** incidents were related to wet refractory and equipment and wet starting blocks. **Termination** VDC **Casting** incidents occurred due to wet/rusty drain pans and over-flow onto a wet floor. **Transfer** and **Reduction** incidents were primarily related to wet/rusty equipment, tools and drain pans as well as tap-outs onto a wet floor.

Figure 42 provides the main causes for the **49 Recycling** incidents reported in 2022. Most incidents occurred in **Melting** (**30**) due to wet charge material: scrap, RSI sow and dross. **Transfer** incidents were primarily related to wet/rusty drain pans and wet tools while and **Sow Casting** incidents were primarily the result of wet/rusty molds or drain pans.

In **Reduction** facilities there were **6 Minor** injuries in 2022 as shown in the **Figure 43** bar chart with **zero Serious** injuries. **Three** occurred in **Casting** and **three** in **Transfer** operations. **Casting** injuries were the result of wet sow molds and a wet starting block. The **three Transfer** injuries were all related to wet sampling molds.

All **six Rolling** plant **Minor** injuries occurred during **Casting** (**Figure 44**). **Three** occurred during **Start-up** bleed-outs, **two** at **Termination** due to wet/rusty drain pans and **one** at **Start-up** with excessive curl.

For **Extrusion** in 2022, **Figure 45**, there was only one **Minor** injury from the **25** explosions, **18 Force 1** and **seven Force 2**. The injury occurred during a cast **Start-up** due to a hang-up. This is the second year in a row with **Extrusion** reporting only one **Minor** injury.

As shown in **Figure 46**, there were no **Recycling** injuries in 2022 from **49** incidents.

Figure 47 summarizes the 2021 injury data by type of **Process Plant** and **Figure 48** shows this same data for 1980 through 2022.

This year, for the first time, there was further incident and injury data analysis of the four **Process Plants (Reduction, Extrusion, Rolling and Recycling)**. **Charts 2 through 5**, below, provide incident, injury and injuries per incident data for these four plant categories for the past 11 years (2012 through 2022). Severity of injury (**Minor, Serious and Fatal**) was not investigated separately in this analysis. These four charts are also provided in **Figures 49 and 50**.

Chart 2
Reduction Plant Incidents, Injuries & % Injuries/Incident
2012 to 2022

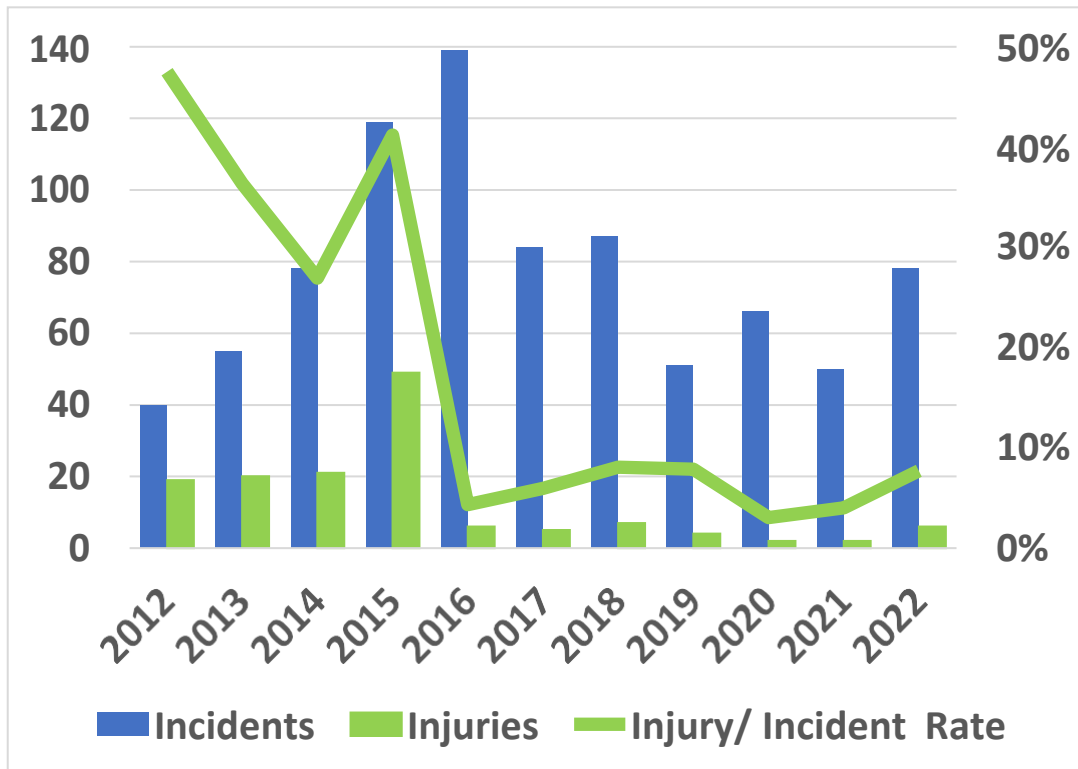


Chart 3
Extrusion Plant Incidents, Injuries & % Injuries/Incident
2012 to 2022

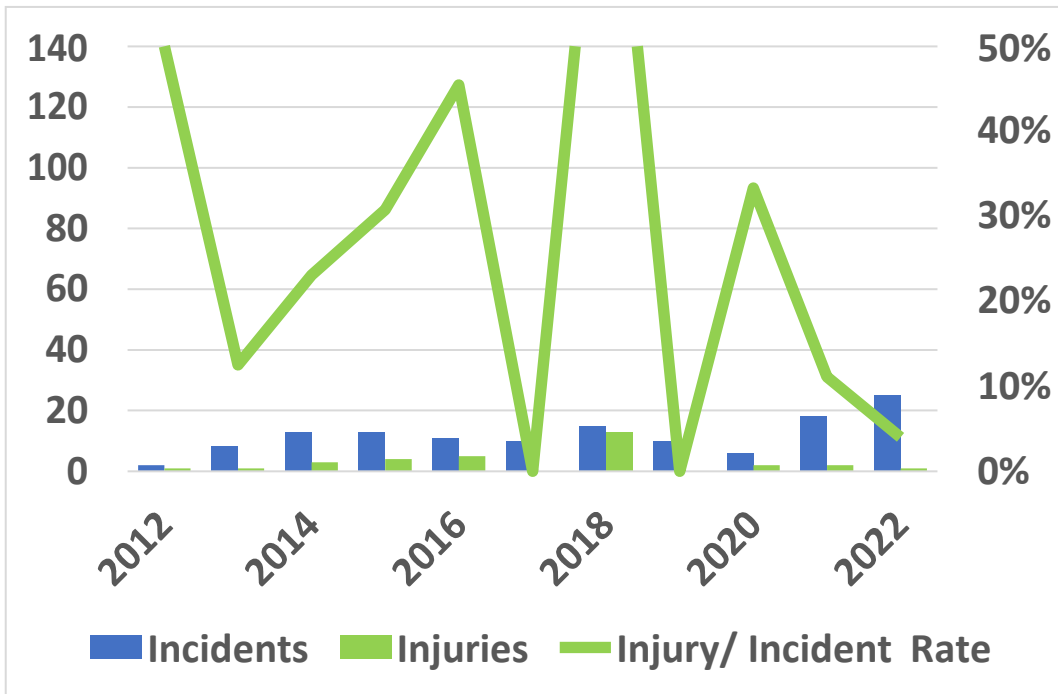


Chart 4
Rolling Plant Incidents, Injuries & % Injuries/Incident
2012 to 2022

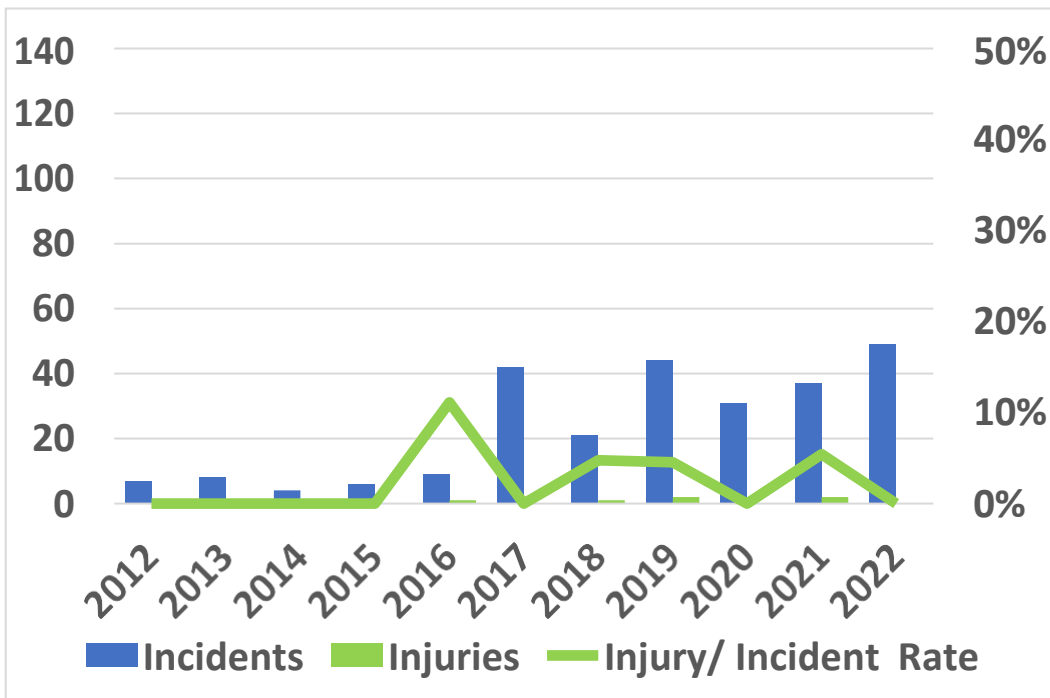
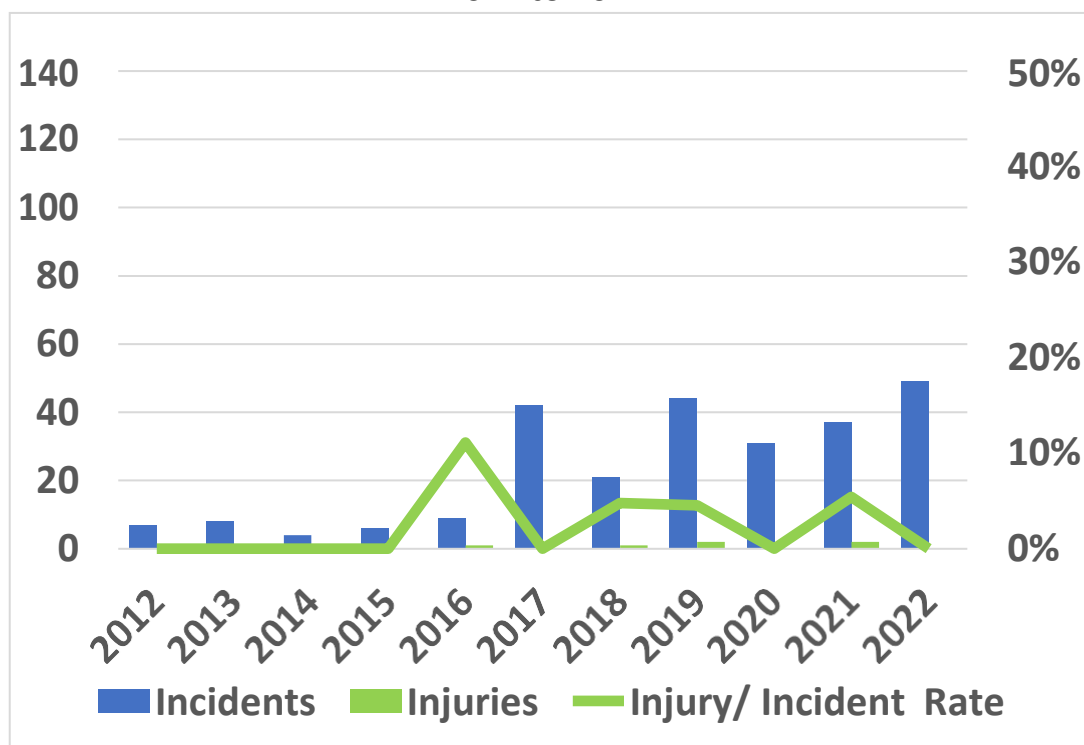


Chart 5
Recycling Plant Incidents, Injuries & % Injuries/Incident
2012 to 2022



From the above charts and **Figures 49** and **50**, 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 the incident per injury rate. Both the number of injuries and injury rate remained low since that time. Reporting of **Recycling** plant incidents increased significantly starting in 2016 from approximately five per year to an average of 37 per year over the past six years. Along with the higher number of injuries in this time frame, the injury rate variability has increased with some years being 5%, but other years at 0%. In comparing **Reduction** and **Recycling** plant injury rates over the last seven years, they averaged 6% and 4% respectively, with significantly more incidents in **Reduction** plants.

Both the **Reduction** and **Recycling** plant injury rates are lower than the **Extrusion** and **Rolling** plant rates, as shown in **Charts 3 and 4** above and **Figure 50**. The number of reported incidents is approximately 3-4X higher in **Rolling** plants 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. **Rolling** plant injuries and injury rates are high compared to **Reduction** and **Recycling**. The number of **Rolling** incidents were very low for the years 2012 through 2014, averaging ten per year in that time frame, similar to

Extrusion. From 2015 through 2022 the average number of **Rolling** incidents increased to 24 per year with an average injury rate of 11%. This is approximately 2X higher than the **Reduction** and **Recycling** injury rates noted above.

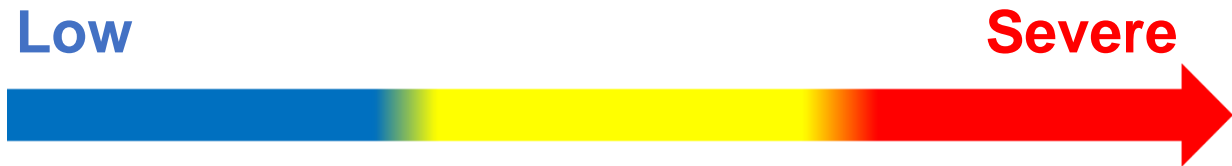
This new plant incident and injury data indicates that further investigation, analysis and discussion should be pursued to determine why higher injury rates are observed in **Rolling** and **Extrusion** compared to **Reduction** and **Recycling**. This may be related to the higher application of the billet and slab VDC Casting processes in these plants compared to **Reduction** and **Recycling**. This additional understanding could lead to reducing injury rates.

The last page of the report after the figures provides an Aluminum Association Molten Metal Incident Report Form. You can also link to the form at:

<https://www.aluminum.org/health-safety>

R T Richter – September 28, 2023

Explosion Rating Force Criteria



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

TABLE 1. Explosion Rating Force Criteria

Sep. 2023



Incidents by Year

1981 – 2022 (Total 4537)

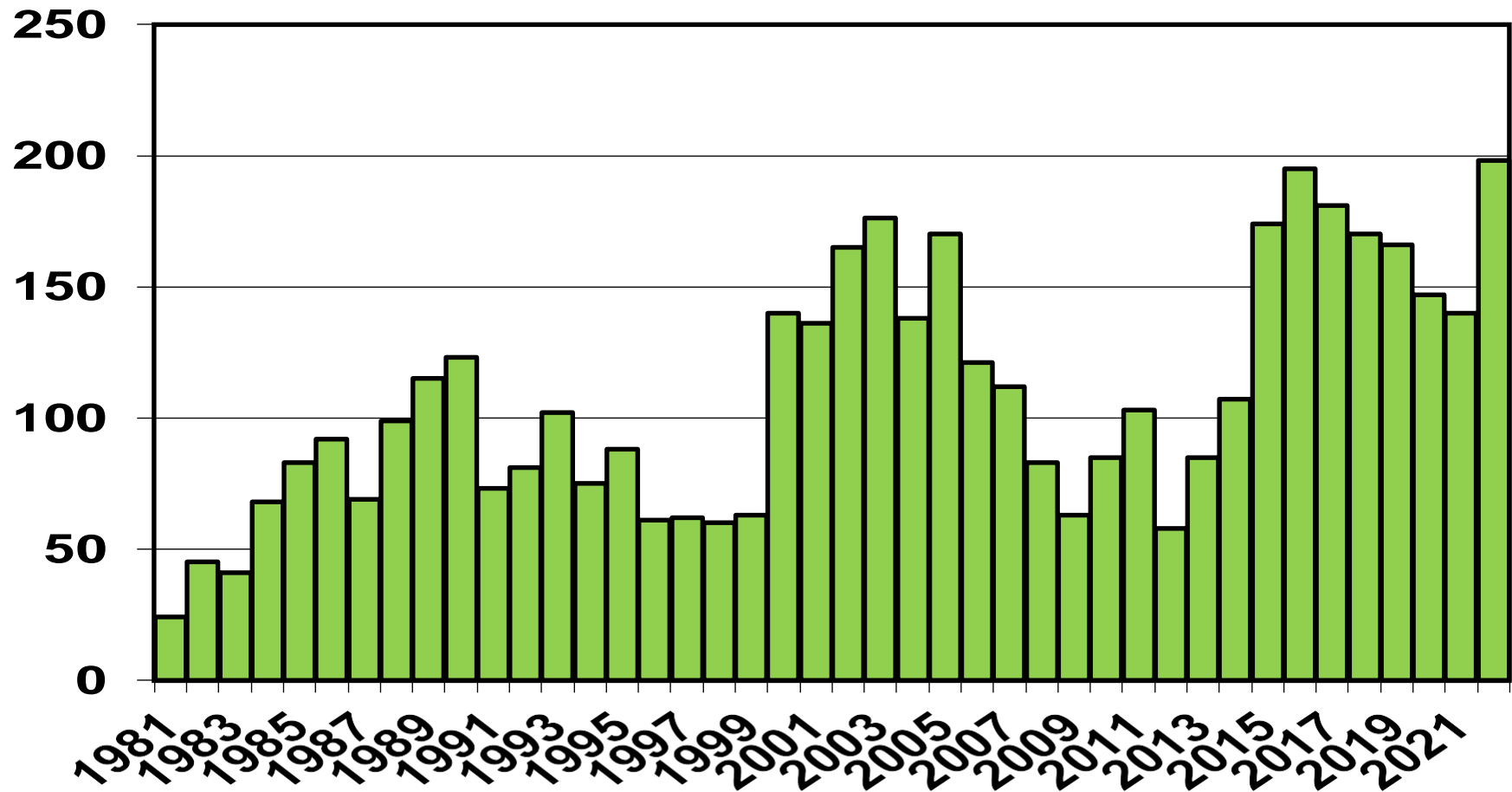


FIGURE 1. Incidents Reported For The Period 1981 – 2022 Sep. 2023 ³



Incidents by Force Level 1981 – 2022 (Total 4537)

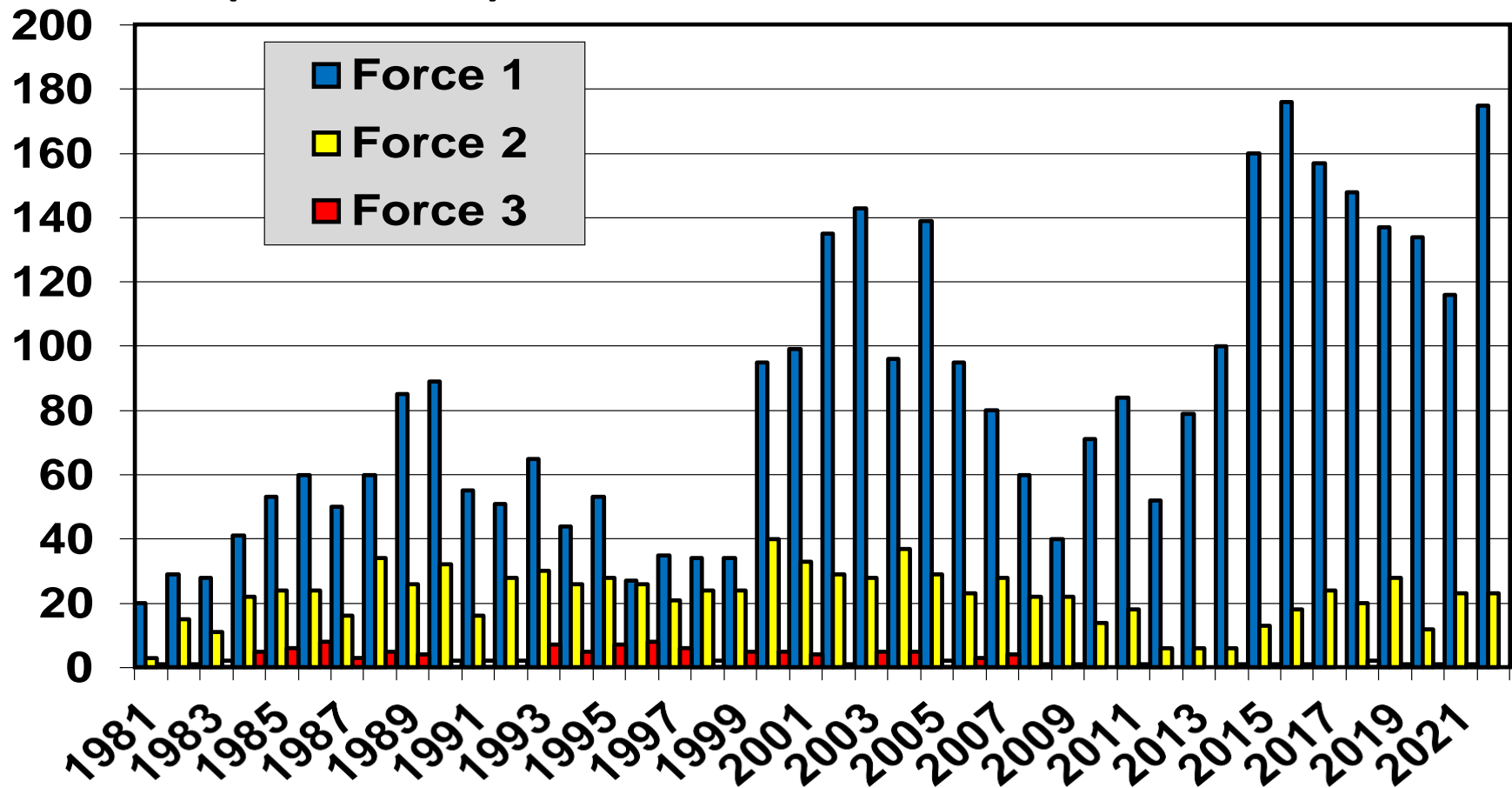


FIGURE 2. Incidents By Force Level 1981 – 2022

Sep. 2023



Incidents by Force Levels 2 & 3 1981 – 2022

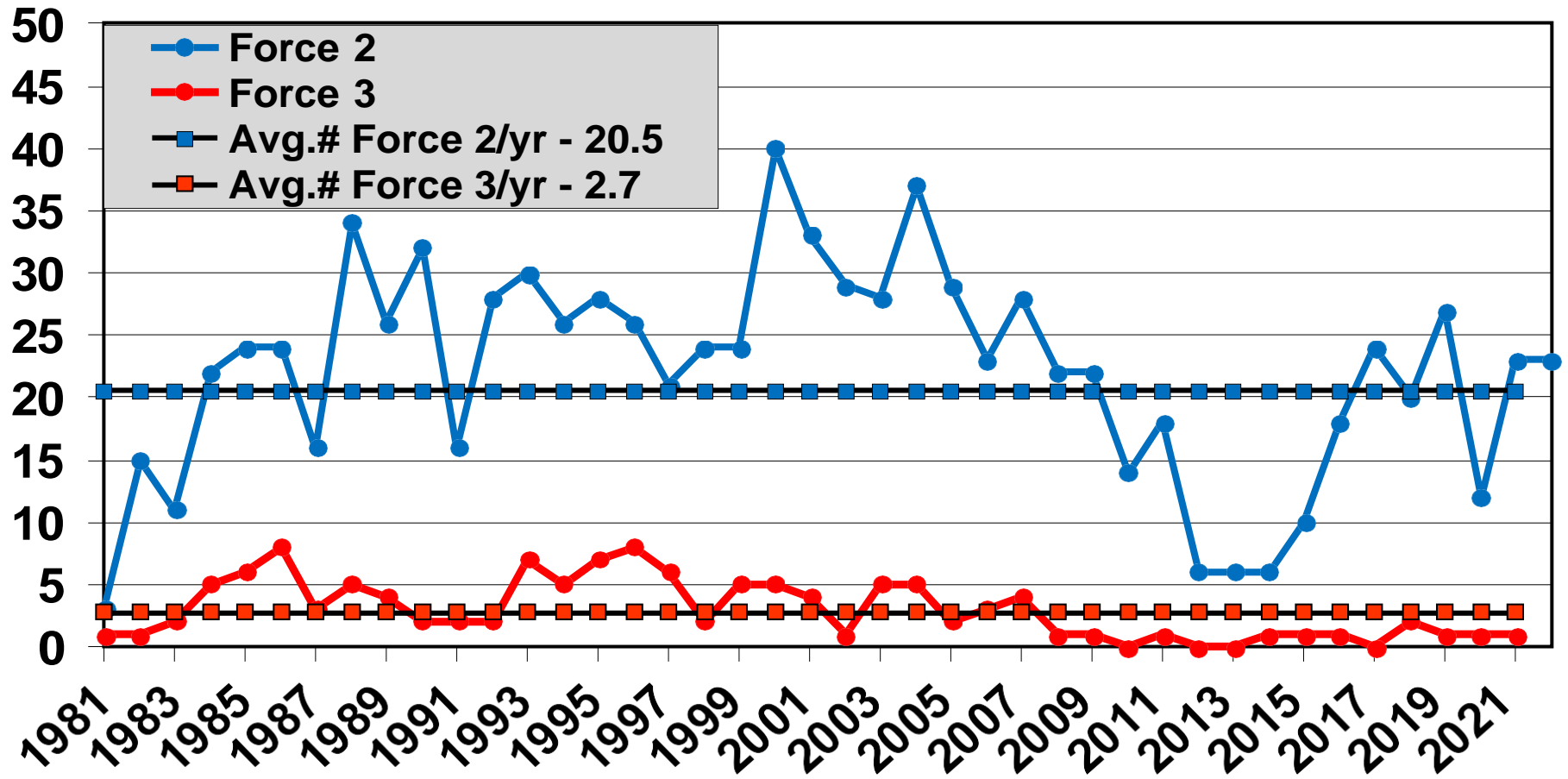


FIGURE 3. Incidents By Force Levels 2 & 3 For 1981 – 2022

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Force 3 Incidents Only 1981 – 2022

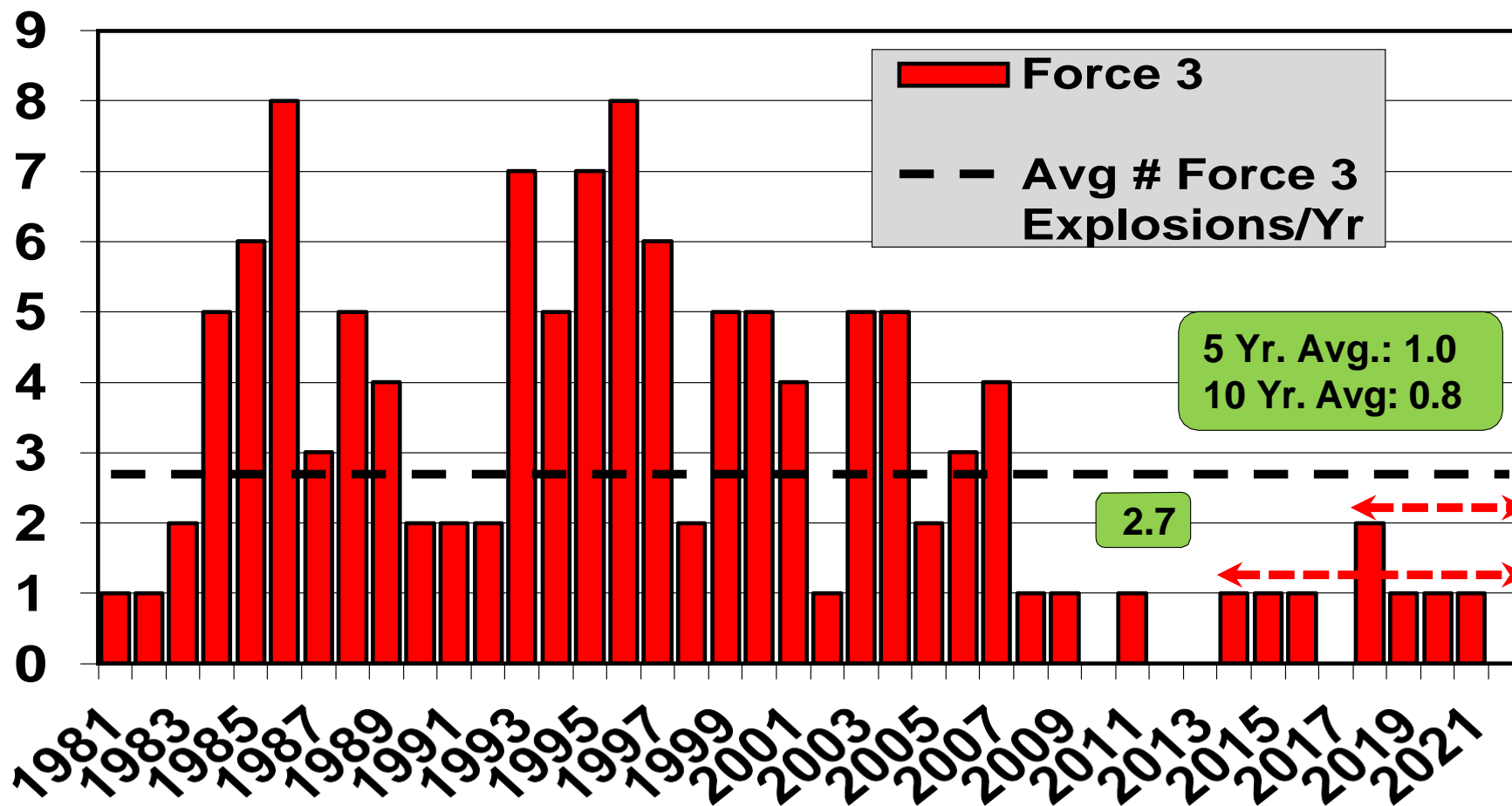


FIGURE 4. Force 3 Incidents For 1981 – 2022

Sep. 2023



Incidents by Force Level 1981 – 2022 (Total 4537)

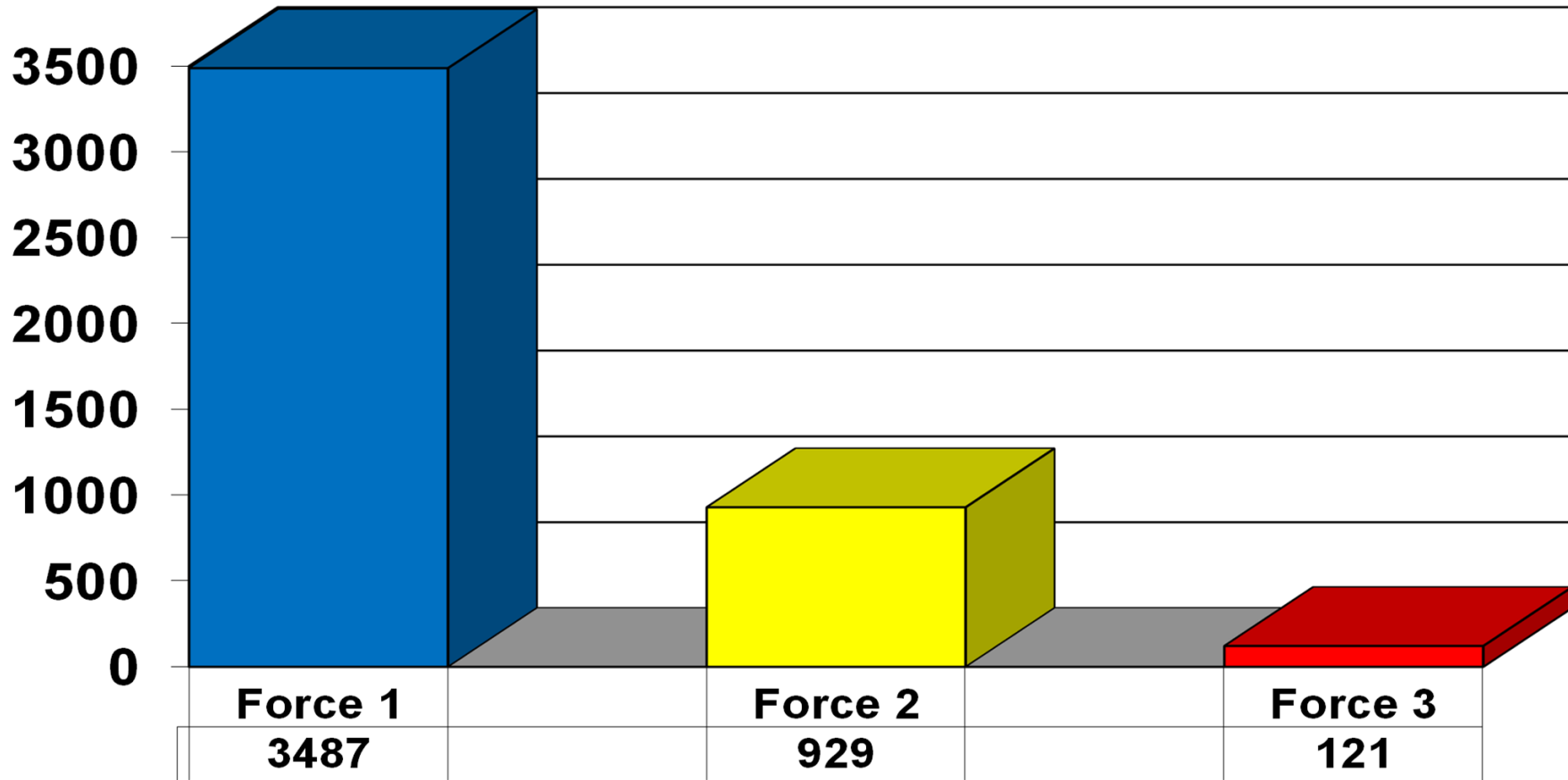


FIGURE 5. Incidents By Force Level 1981 – 2022

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All Force Levels by Percentage 1981 – 2022

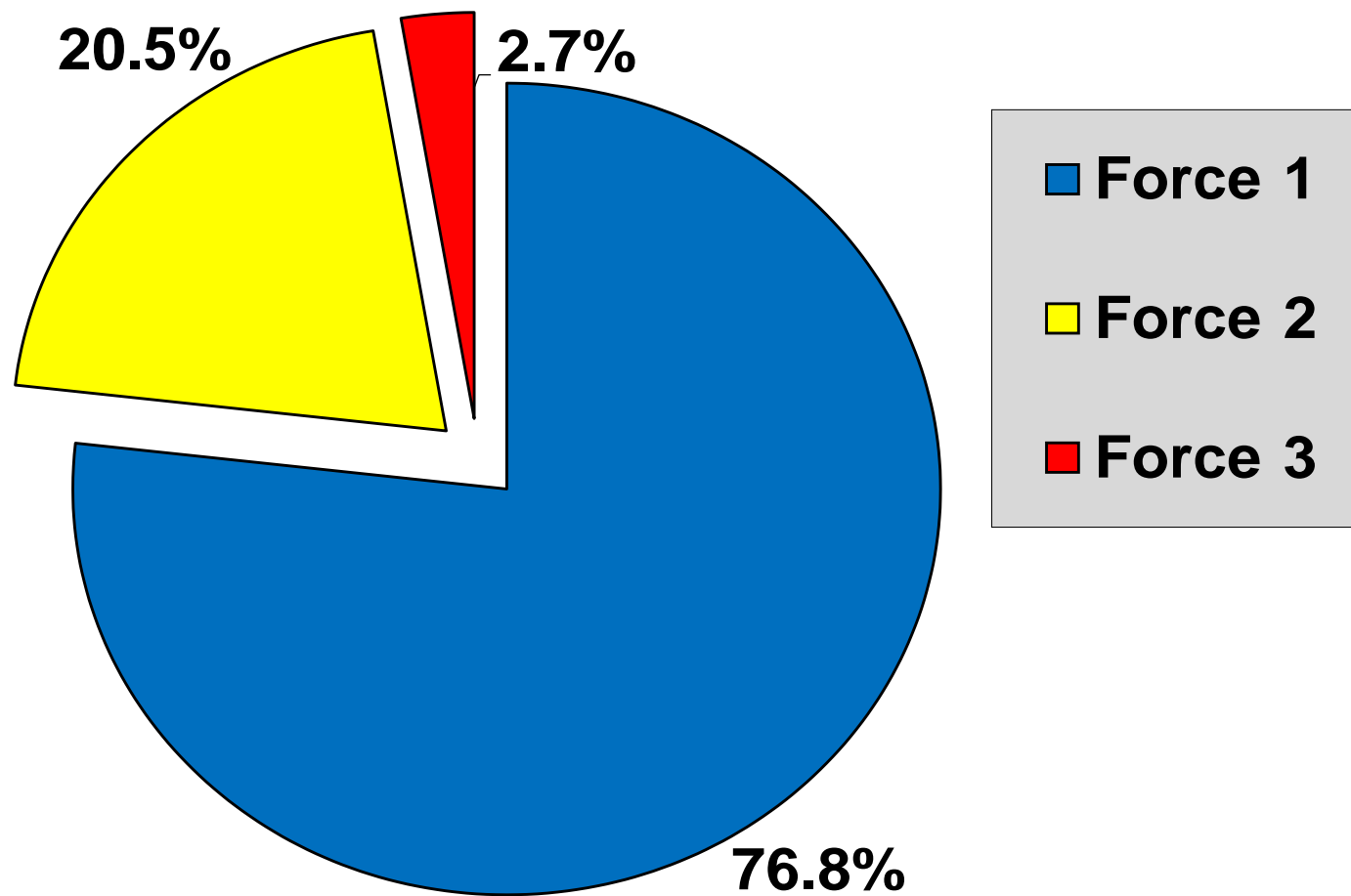


FIGURE 6. All Force Levels By Percentage 1981 – 2022

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Injuries from Incidents 1981 – 2022 (Total 1628)

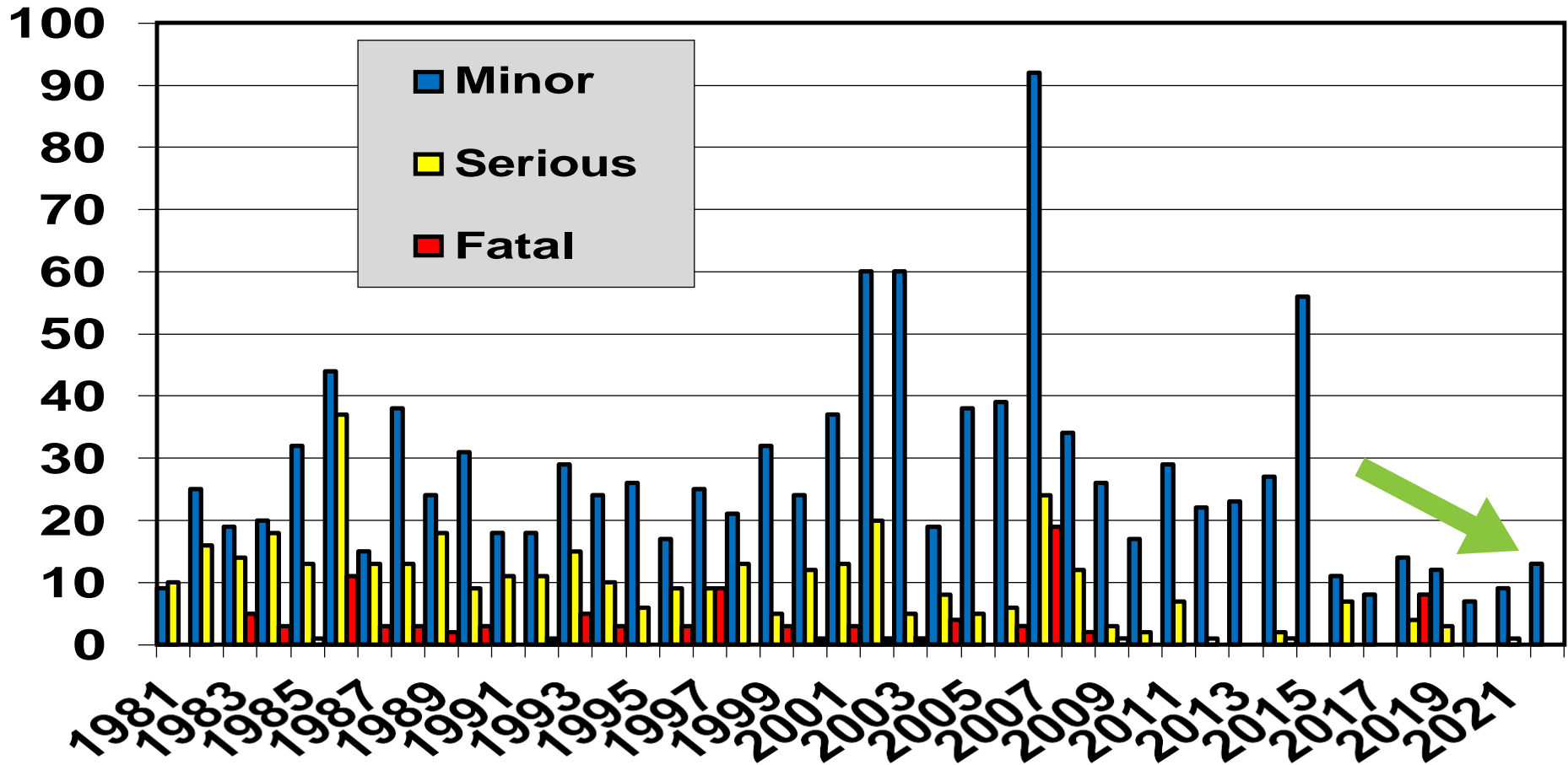


FIGURE 7. Injuries From Incidents For 1981 – 2022

Sep. 2023



% Injuries per Total Annual Incidents 2001 – 2022 (Total 856 Injuries)

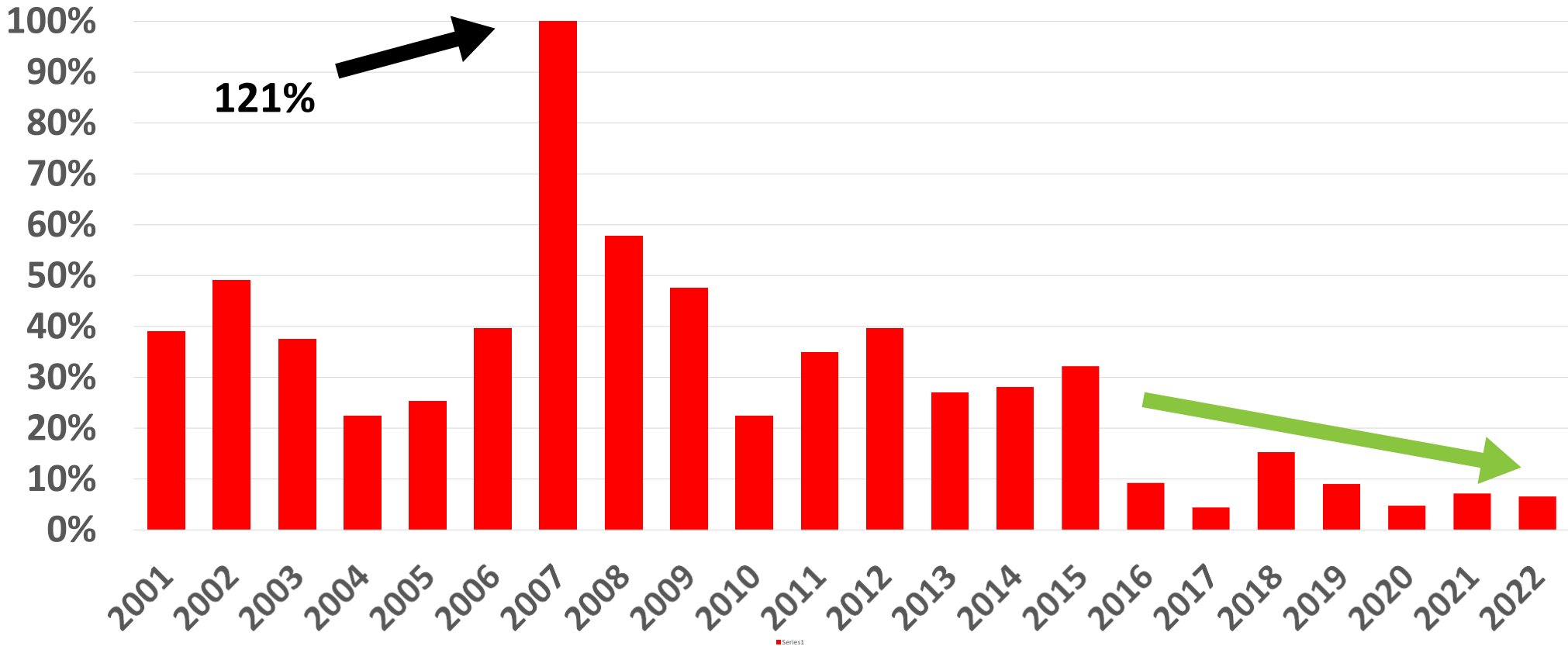


FIGURE 8. % Injuries/Total Annual Incidents 2001 – 2022

Sep. 2023



Average # of Injuries / Year from Explosions

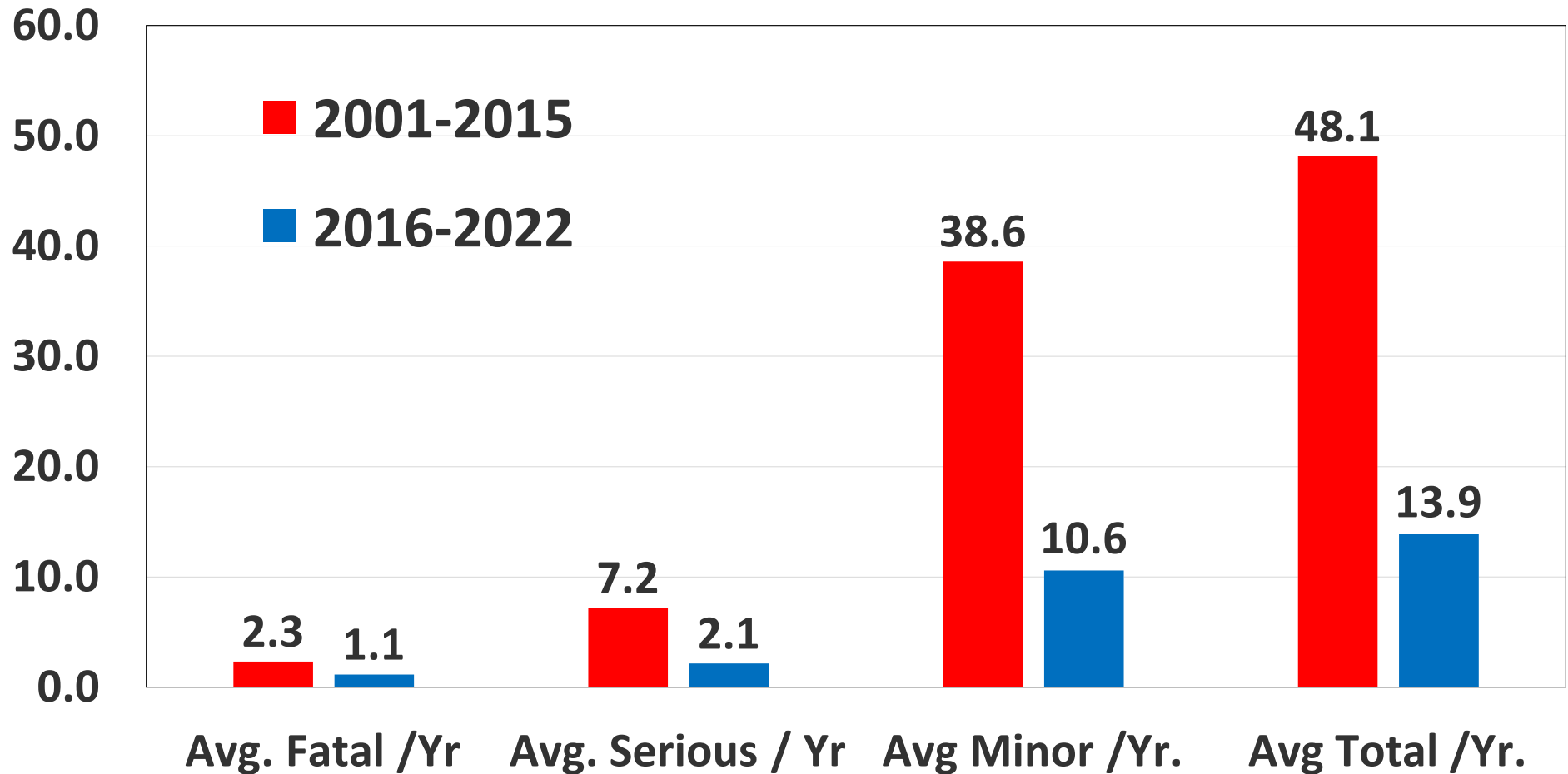


FIGURE 9. Avg. # Injuries / Yr. For 2001-2015 & 2016-2022

Sep. 2023

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Injuries by Severity – Total 1628 1981 – 2022

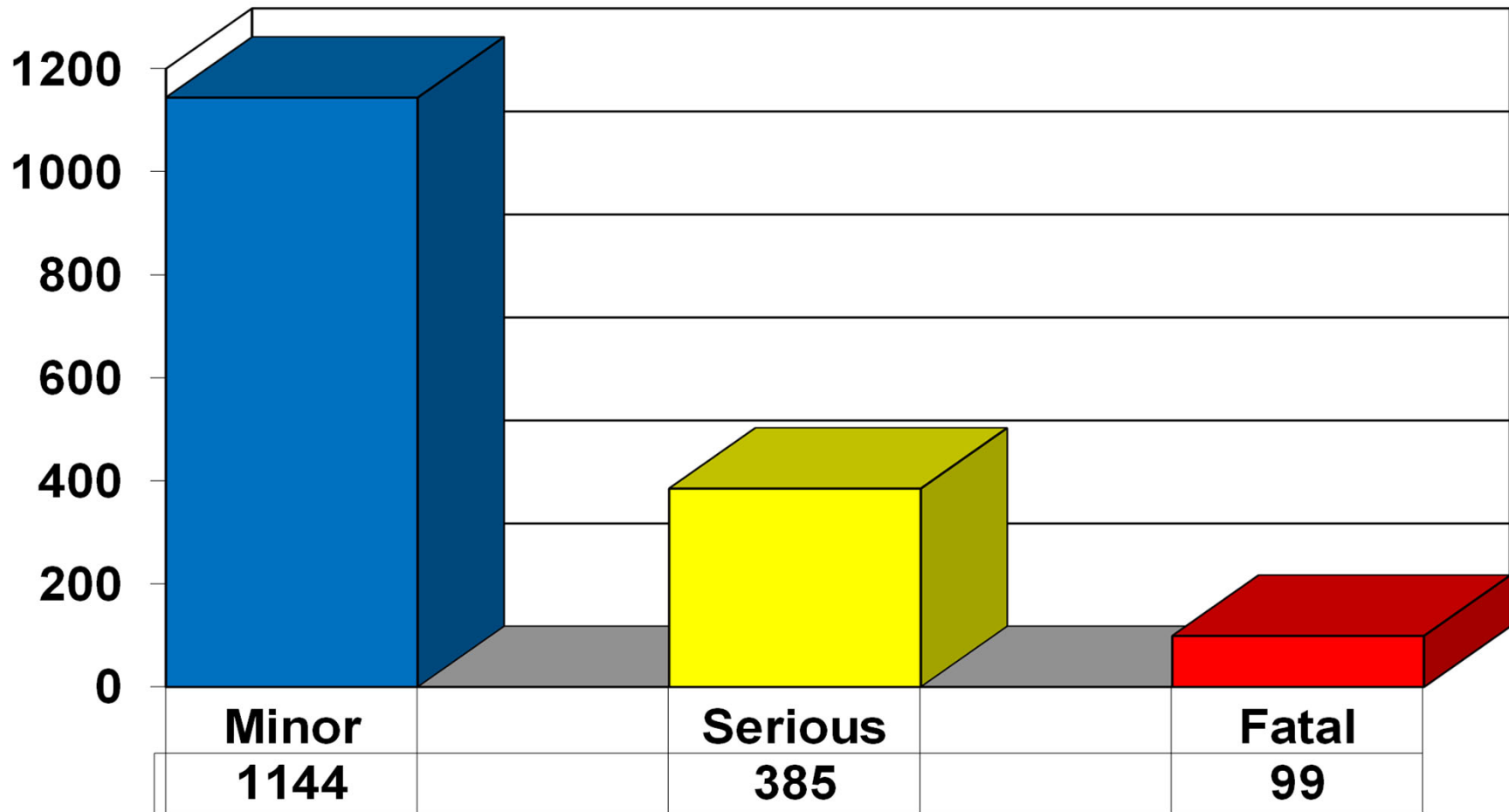


FIGURE 10. Injuries By Severity For 1981 – 2022

Sep. 2023¹²



Injury Levels by Percentage 1981 - 2022

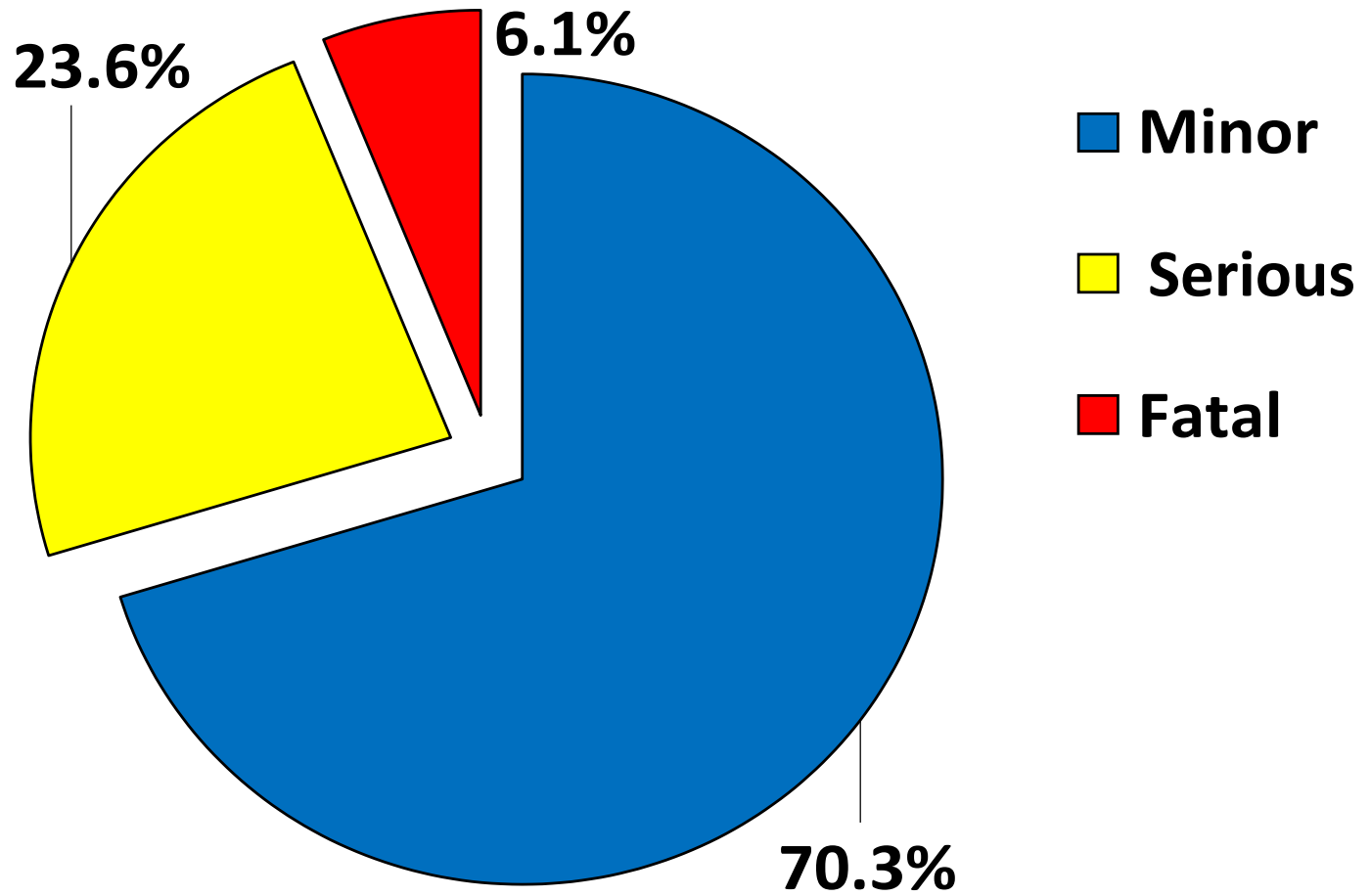


FIGURE 11. Injuries Levels By Percentage For 1981 – 2022



Injury Risk per 100 Explosions 1981 - 2022

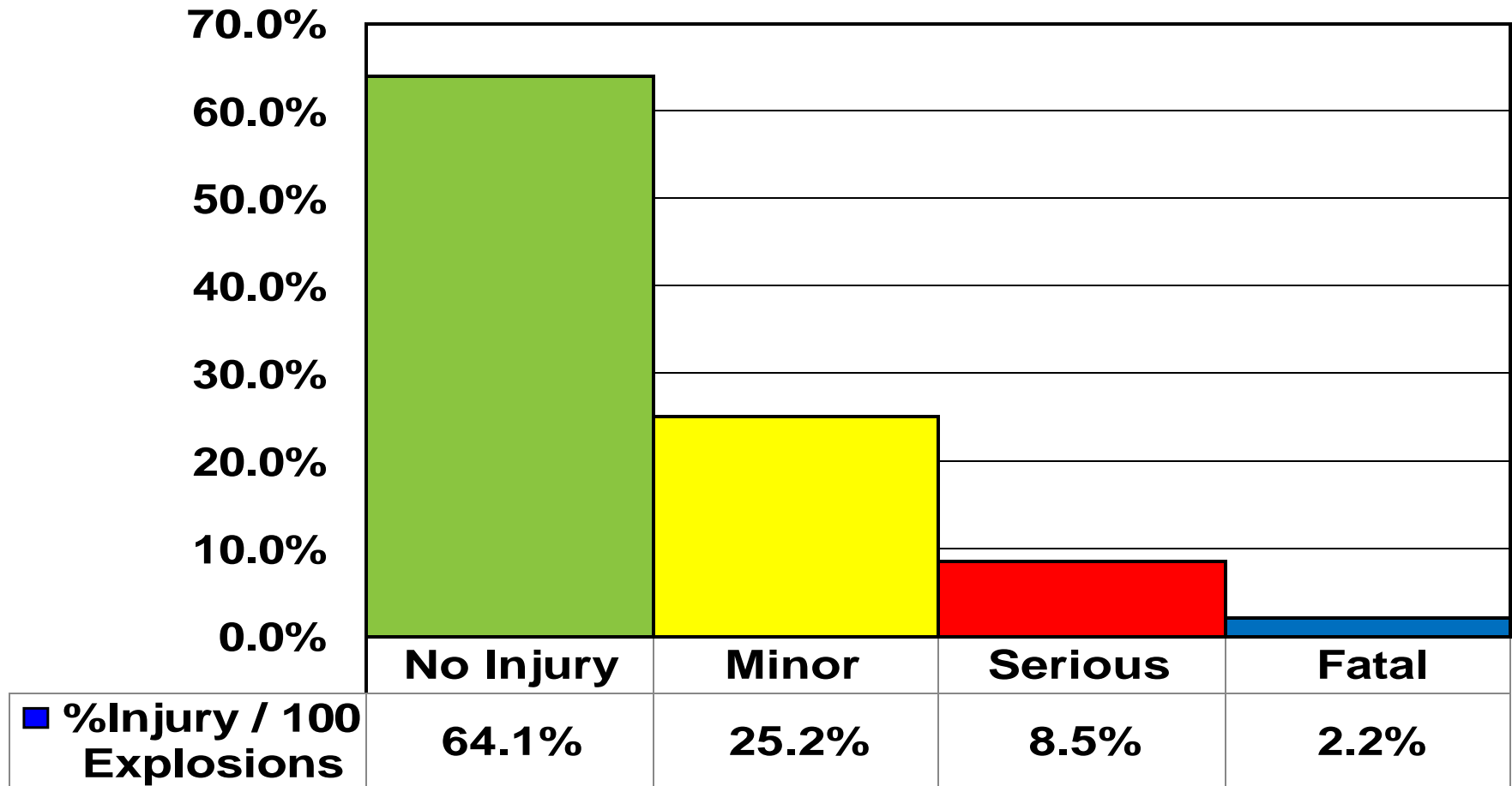


FIGURE 12. Injury Risk Per 100 Explosions For 1981 – 2022 Sep. 2023 ¹⁴



Fatalities from Explosions 1981 - 2022

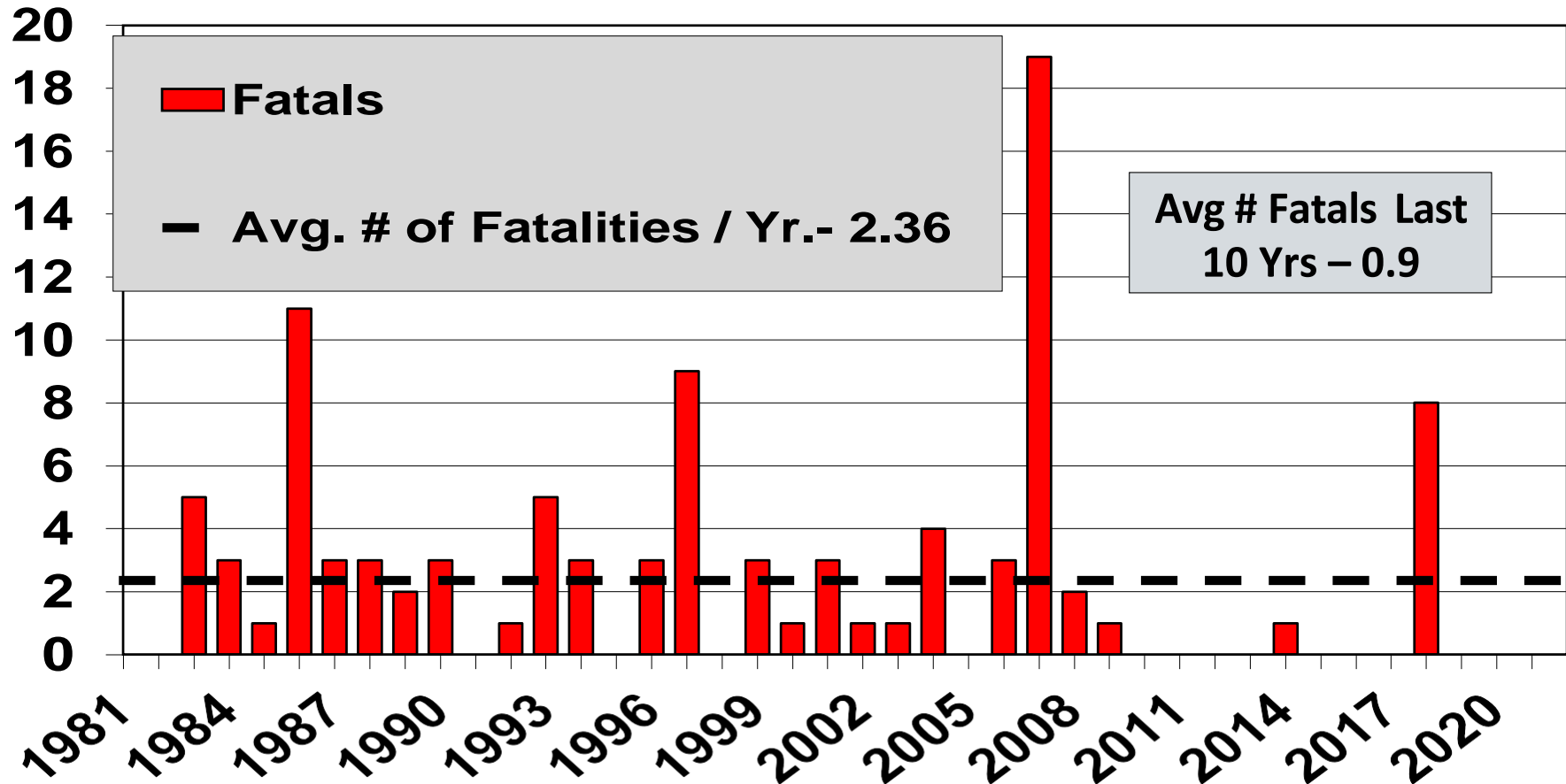


FIGURE 13. Fatalities From Explosions For 1981 – 2022

Sep. 2023



Force Level Incidents by Operation – 2022

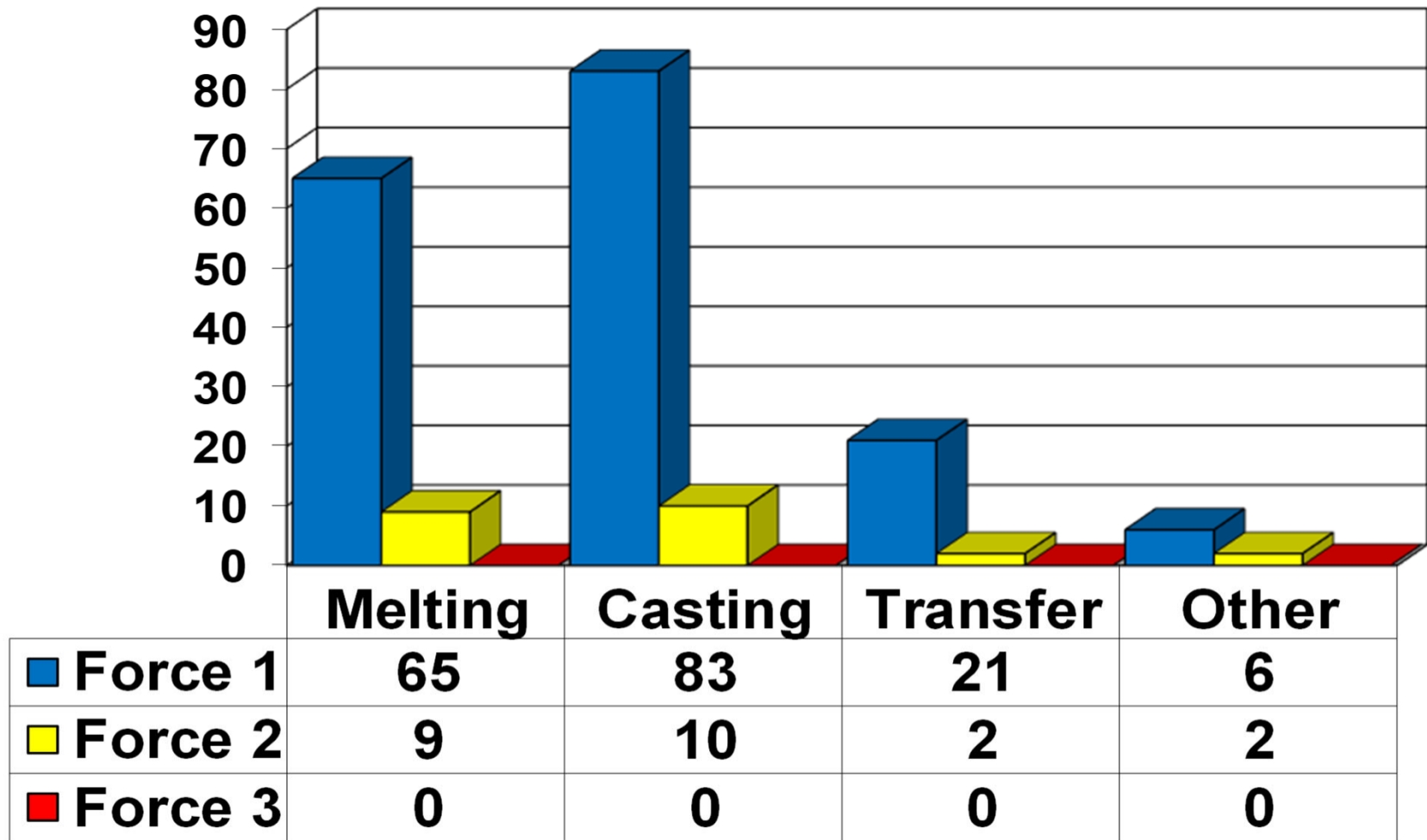


FIGURE 14. Force Level Incidents By Operation For 2022 Sep. 2023



Force Level Incidents by Operation 1980 – 2022

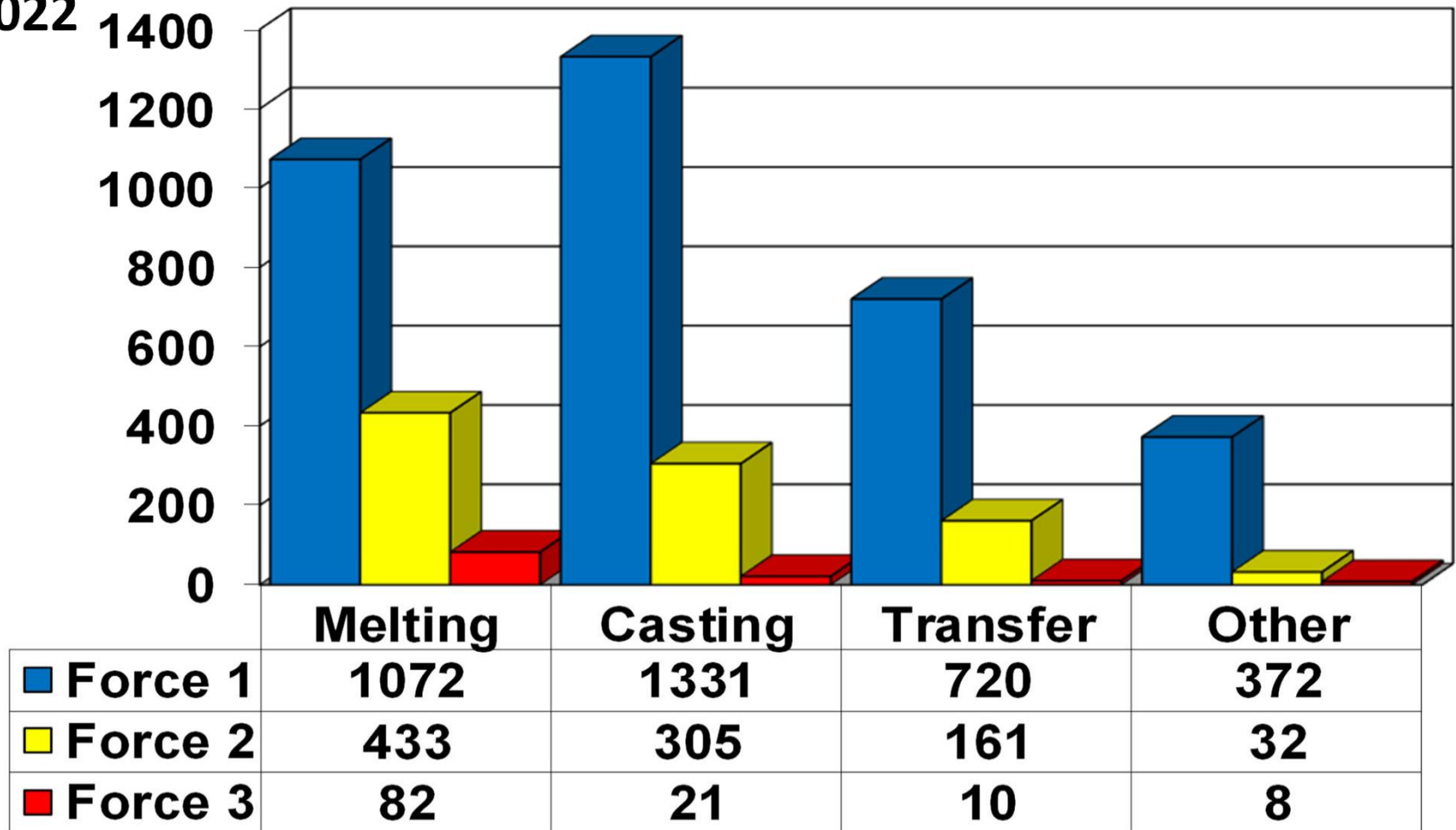


FIGURE 15. Force Level Incidents By Operation For 1980 – 2022 Sep. 2023 ¹⁷



Melting Injuries and Incidents 1990 – 2022 (Total 334 Injuries)

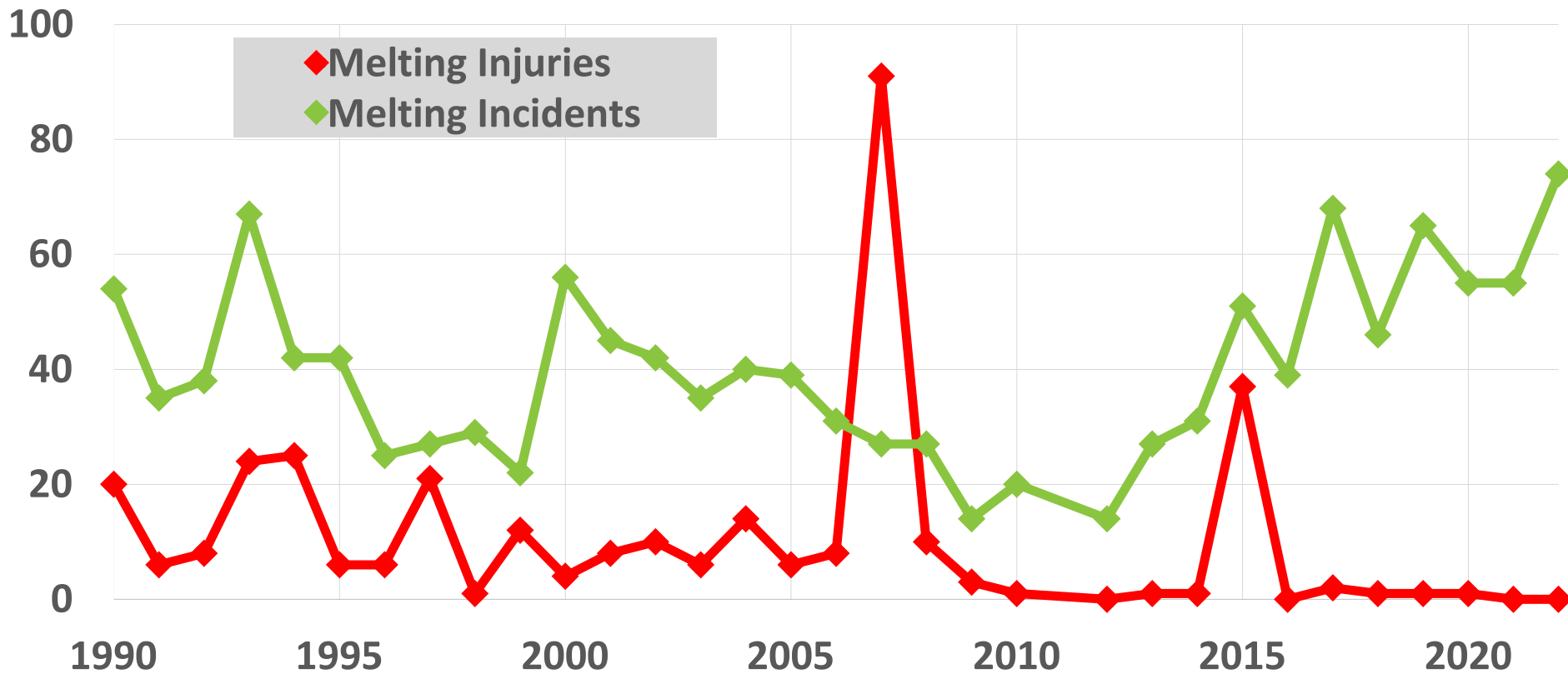


FIGURE 16. Melting Injuries and Incidents 1990 – 2022

Sep. 2023¹⁸



Melting Injuries per Incidents 1990 – 2022

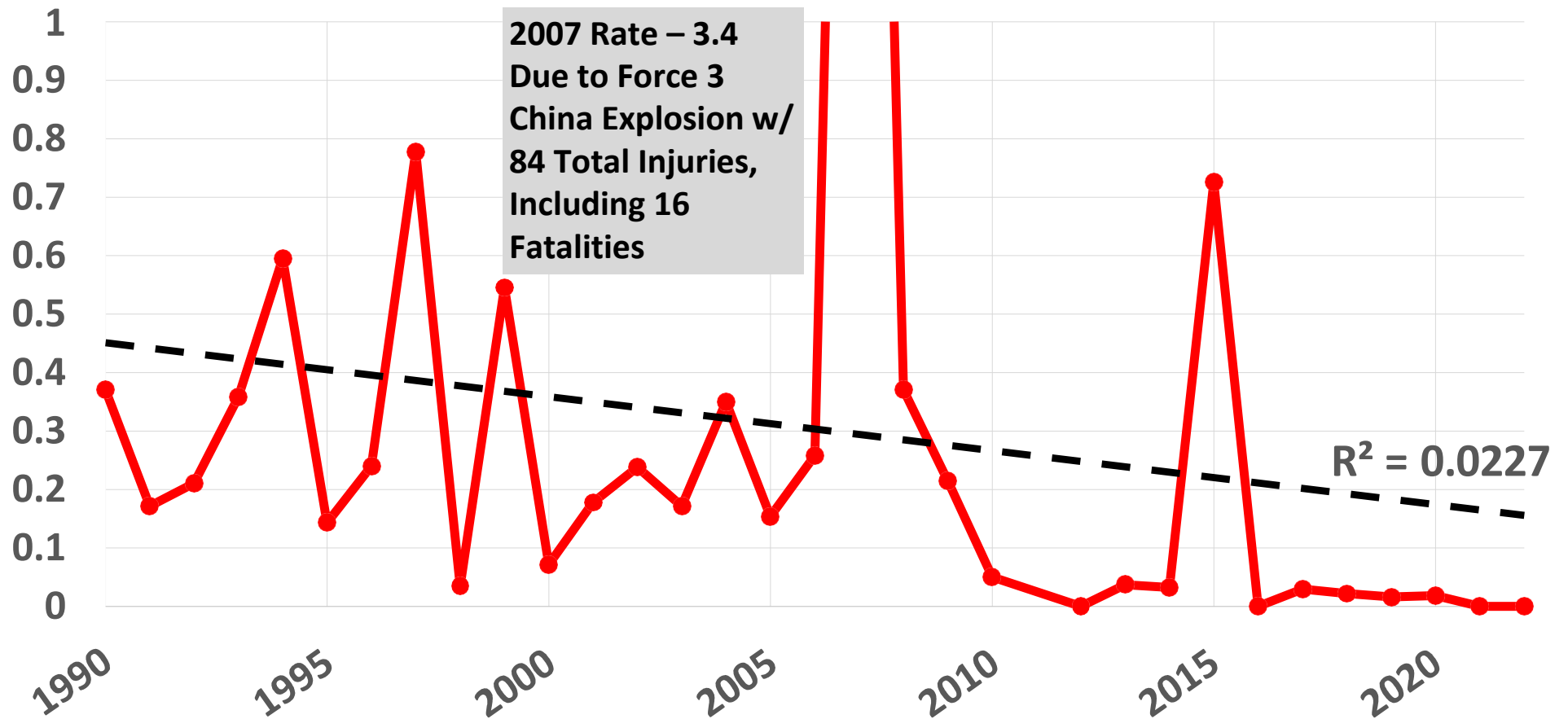


FIGURE 17. Melting Injuries Per Incidents 1990 – 2022

Sep. 2023 19



Casting Injuries and Incidents 1990 – 2022 (Total 358 Injuries)

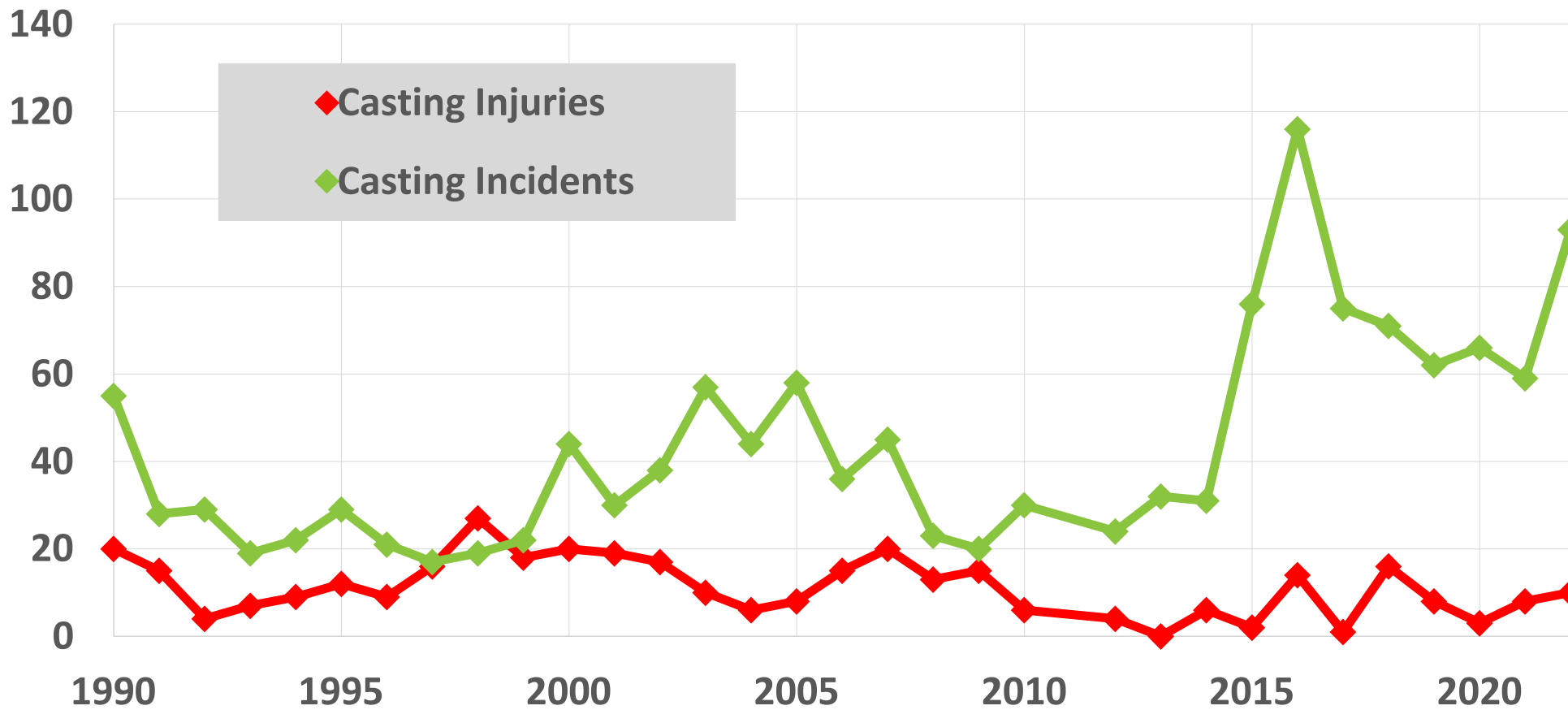


FIGURE 18. Casting Injuries and Incidents 1990 – 2022

Sep. 2023



Casting Injuries per Incidents 1990 – 2022

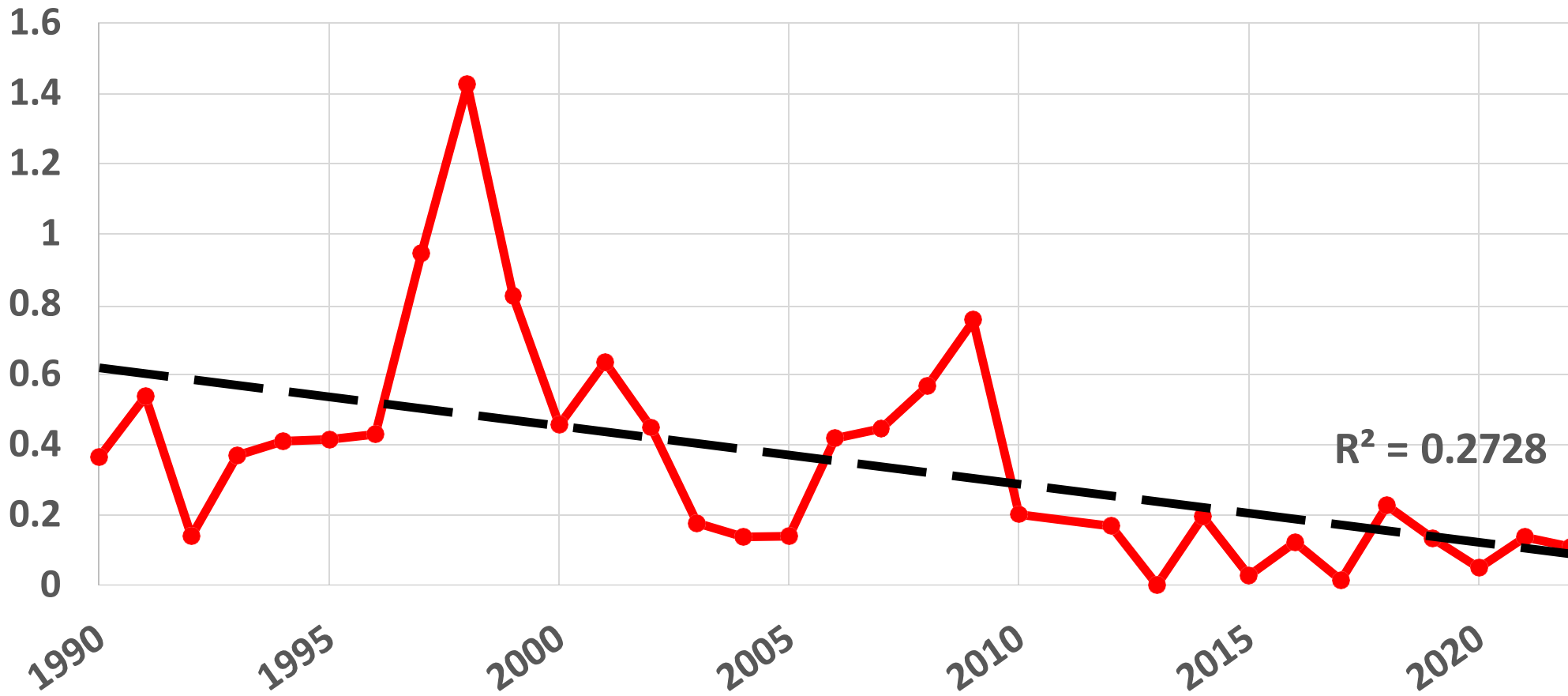


FIGURE 19. Casting Injuries Per Incidents 1990 – 2022

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Transfer Injuries and Incidents 1990 – 2022 (Total 238 Injuries)

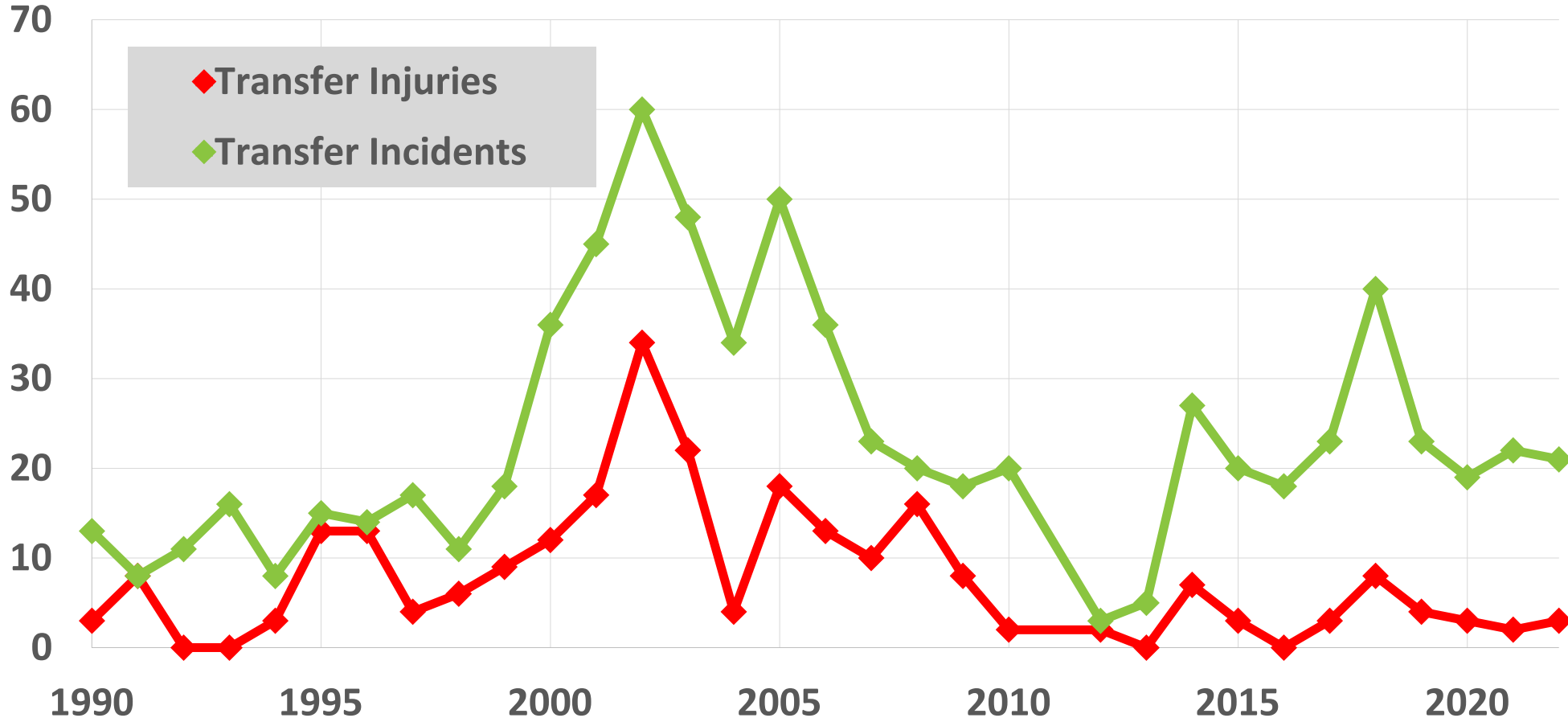


FIGURE 20. Transfer Injuries and Incidents 1990 – 2022

Sep. 2023 ²²



Transfer Injuries per Incidents 1990 – 2022

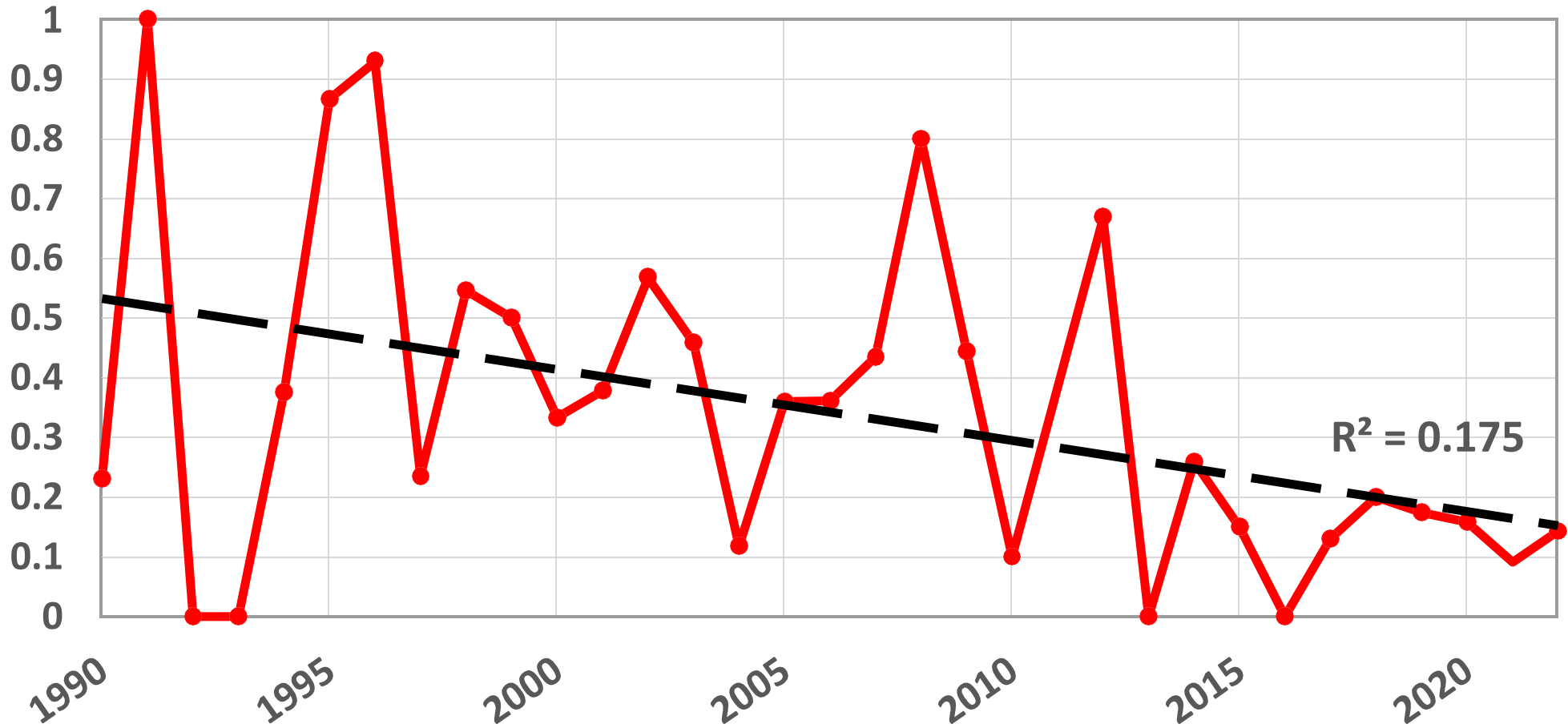


FIGURE 21. Transfer Injuries Per Incidents 1990 – 2022

Sep. 2023



74 Melting Explosions – 2022

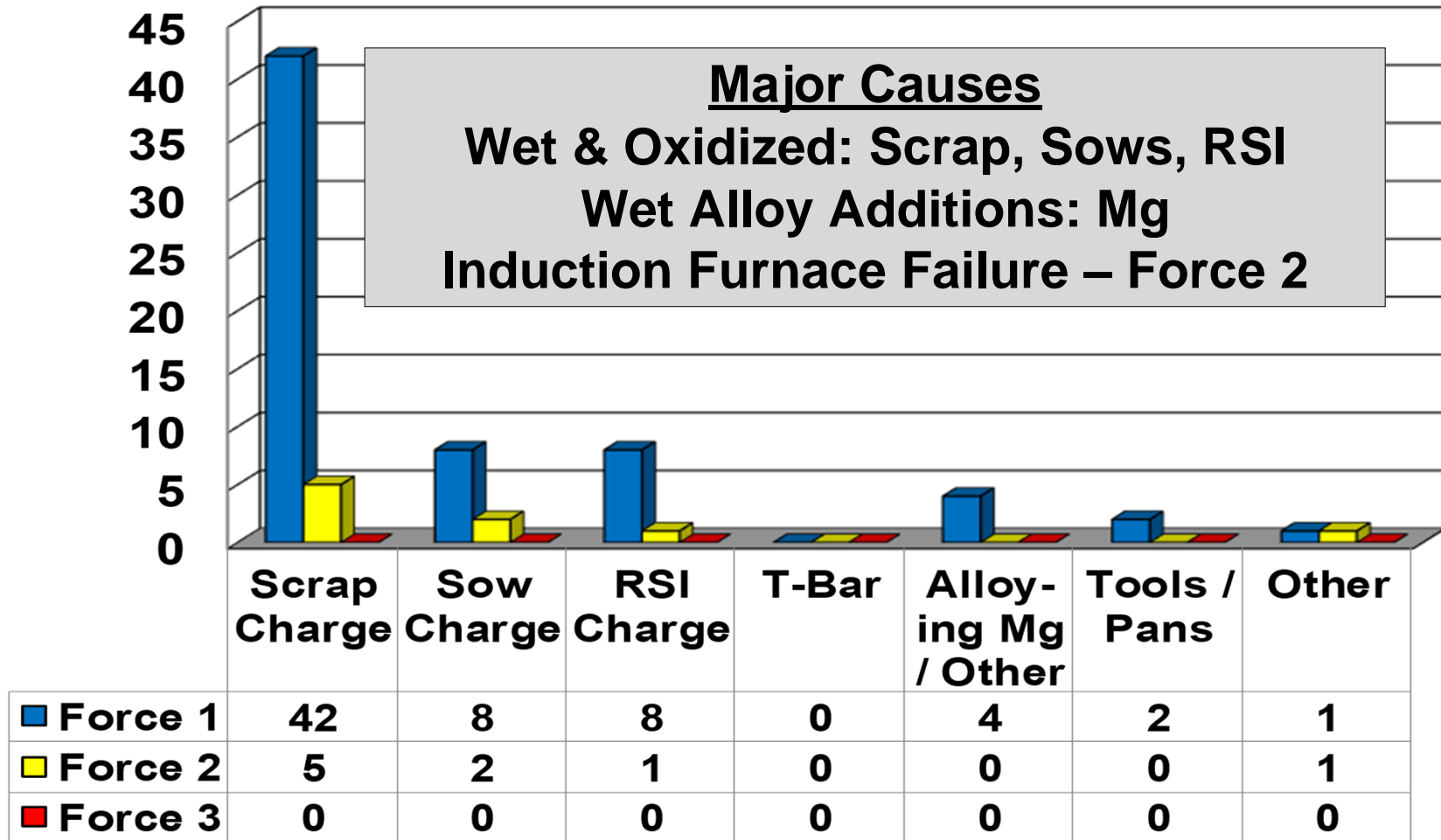


FIGURE 22. Melting Explosions By Cause For 2022

Sep. 2023



Melting Explosions – Charge Material Involved 1980 – 2022

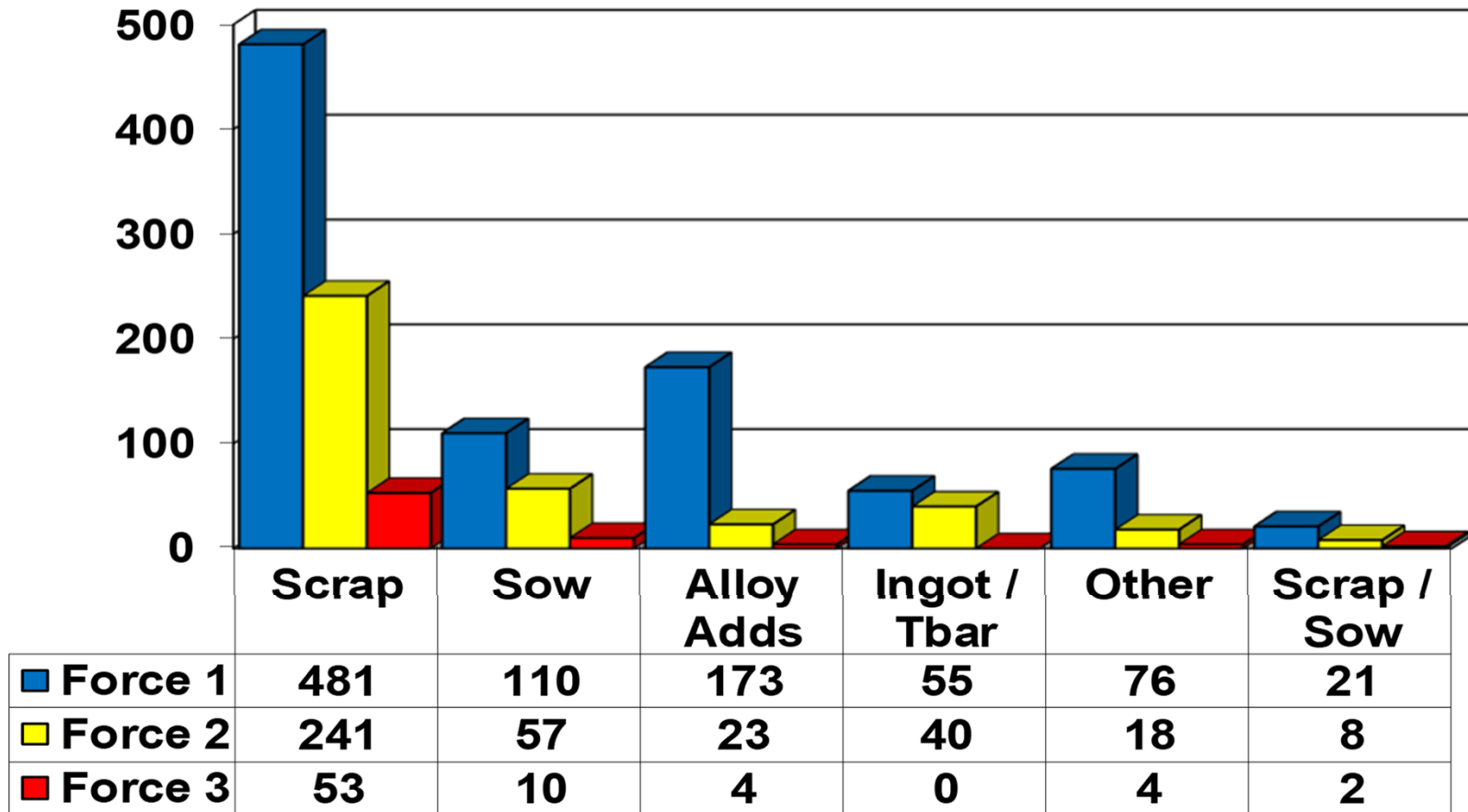


FIGURE 23. Melting Explosions By Charge Material 1980 – 2022 Sep. 2023 ²⁵



93 Casting Explosions – 2022

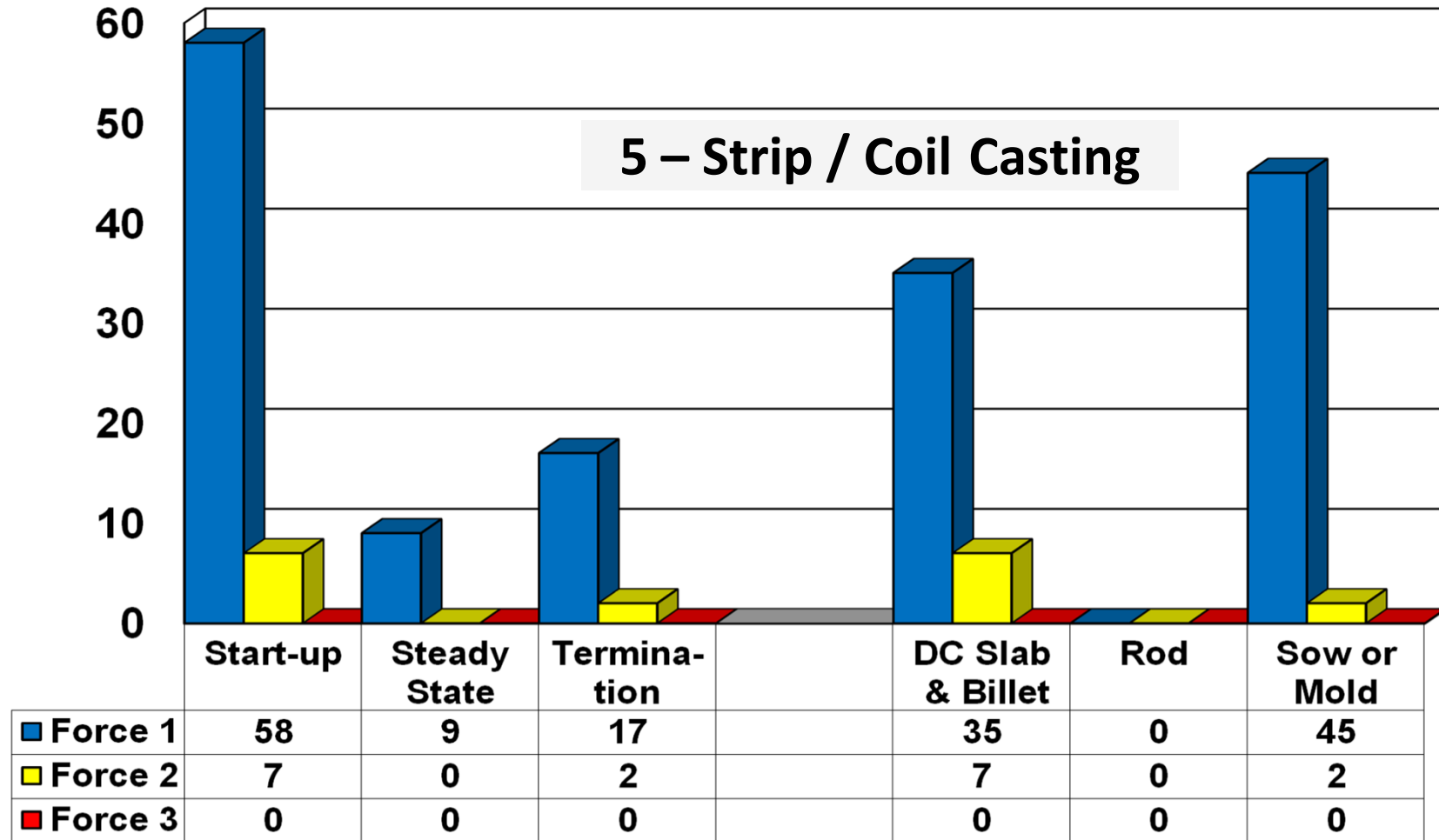


FIGURE 24. Casting Explosions For 2022

Sep. 2023



DC/HDC/EMC Explosions by Cast Segment 1980 – 2022

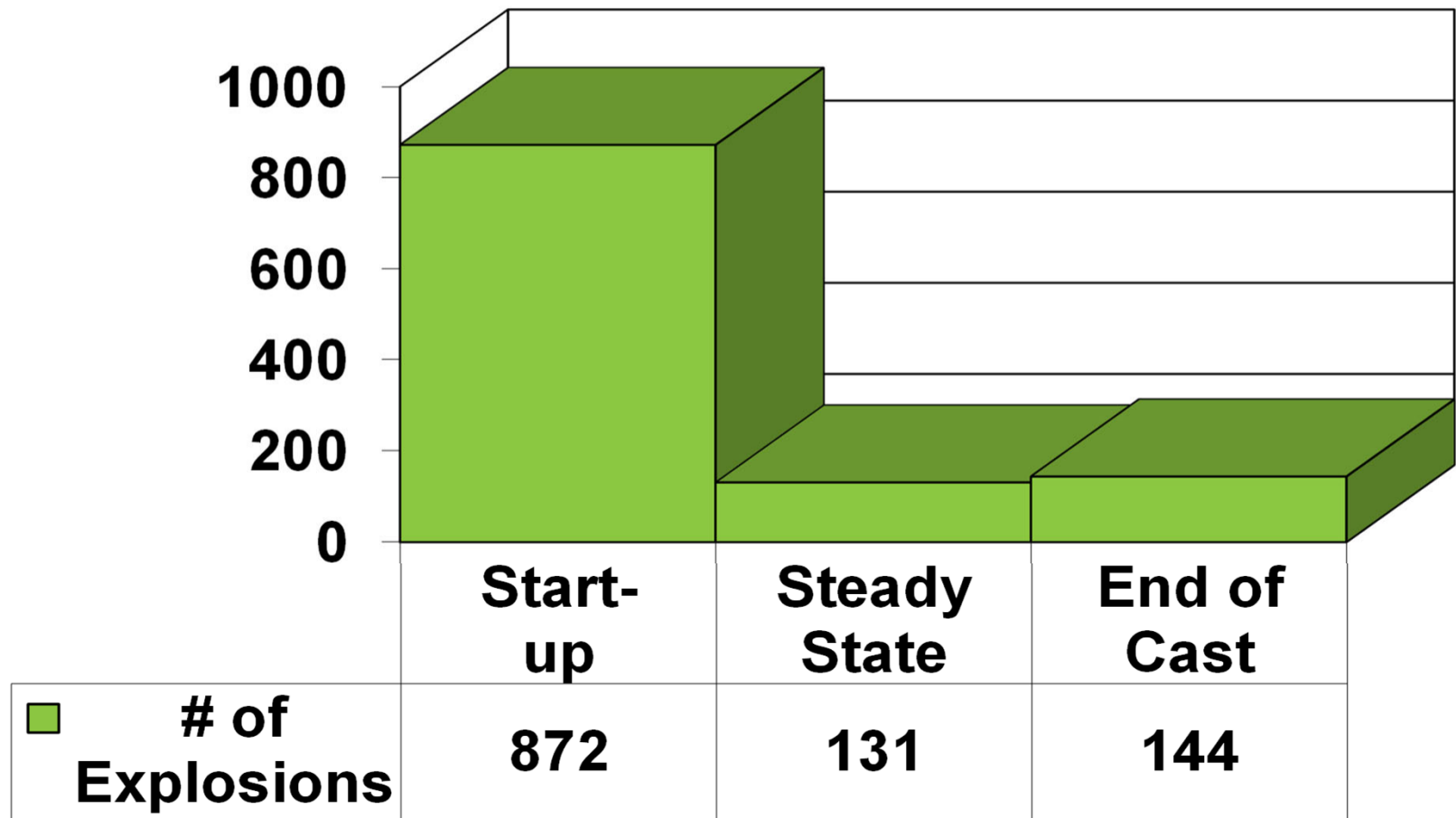


FIGURE 25. Casting Explosions By Cast Segment 1980 – 2022 Sep. 2023 ²⁷



Major Causes of 93 Casting Incidents – 2022

- **DC Start-up Issues: Wet Starting Blocks, Wet Equipment / Launder, Butt Curl – Hang-ups, Bleed-outs, Equipment Failures**
- **DC Steady State Issues: Bleed Out – Surface Tears**
- **DC Termination Issues: Wet / Rusty Drain Pan, Ingot Head Under Water, Metal on Floor**
- **Strip / Coil Casting Termination Issues: Wet / Rusty Drain Pan**
- **Sow / Mold Casting Issues: Wet / Cracked Molds, Wet Refractory, Equipment & Wet Tools**

FIGURE 26. Major Causes of Casting Incidents For 2022

Sep. 2023



Major Causes of Casting Explosions 2015 – 2022

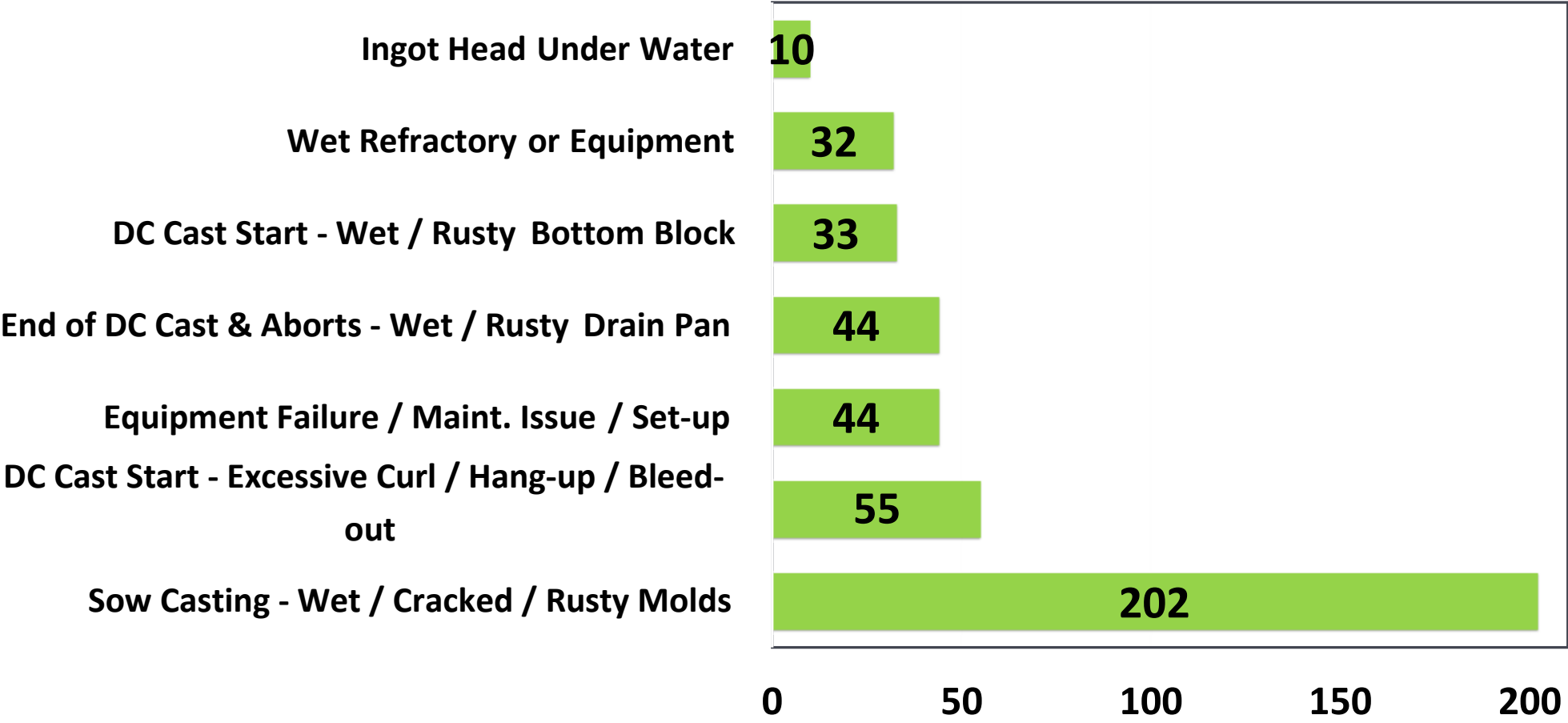


FIGURE 27. Casting Explosions by Major Causes 2015 – 2022 Sep. 2023 ²⁹



Major Causes of Force 2 & 3 Casting Explosions 2015 – 2022

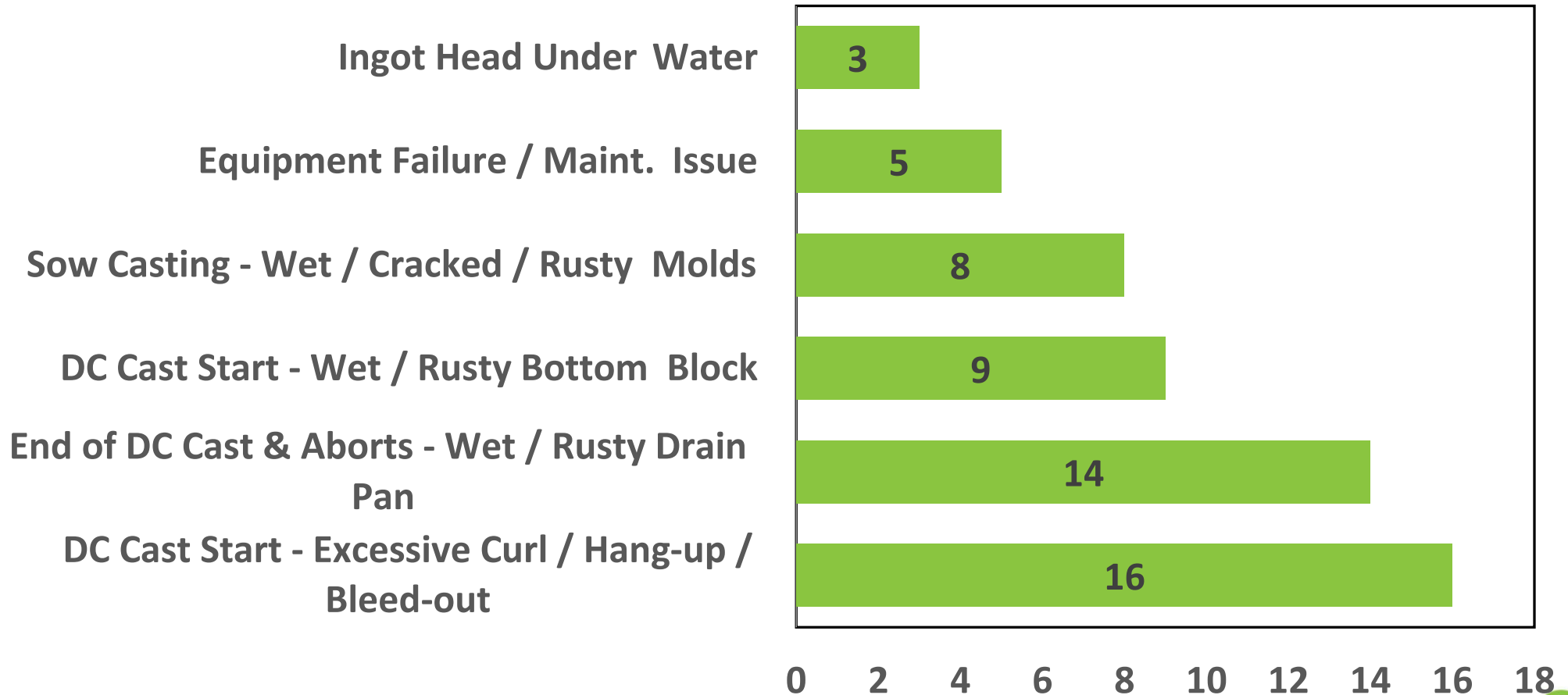


FIGURE 28. Casting Explosions by Major Causes 2015 – 2022 Sep. 2023 ³⁰



Major Causes of 22 Transfer Explosions – 2022

13 - Wet Hand or Furnace Tools, Equipment
9 - Wet / Rusty Drain or Skim Pan
1 – Metal on Floor

FIGURE 29. Causes of Transfer Explosions For 2022

Transfer Explosions by Equipment 1980 – 2022 (Total 884)

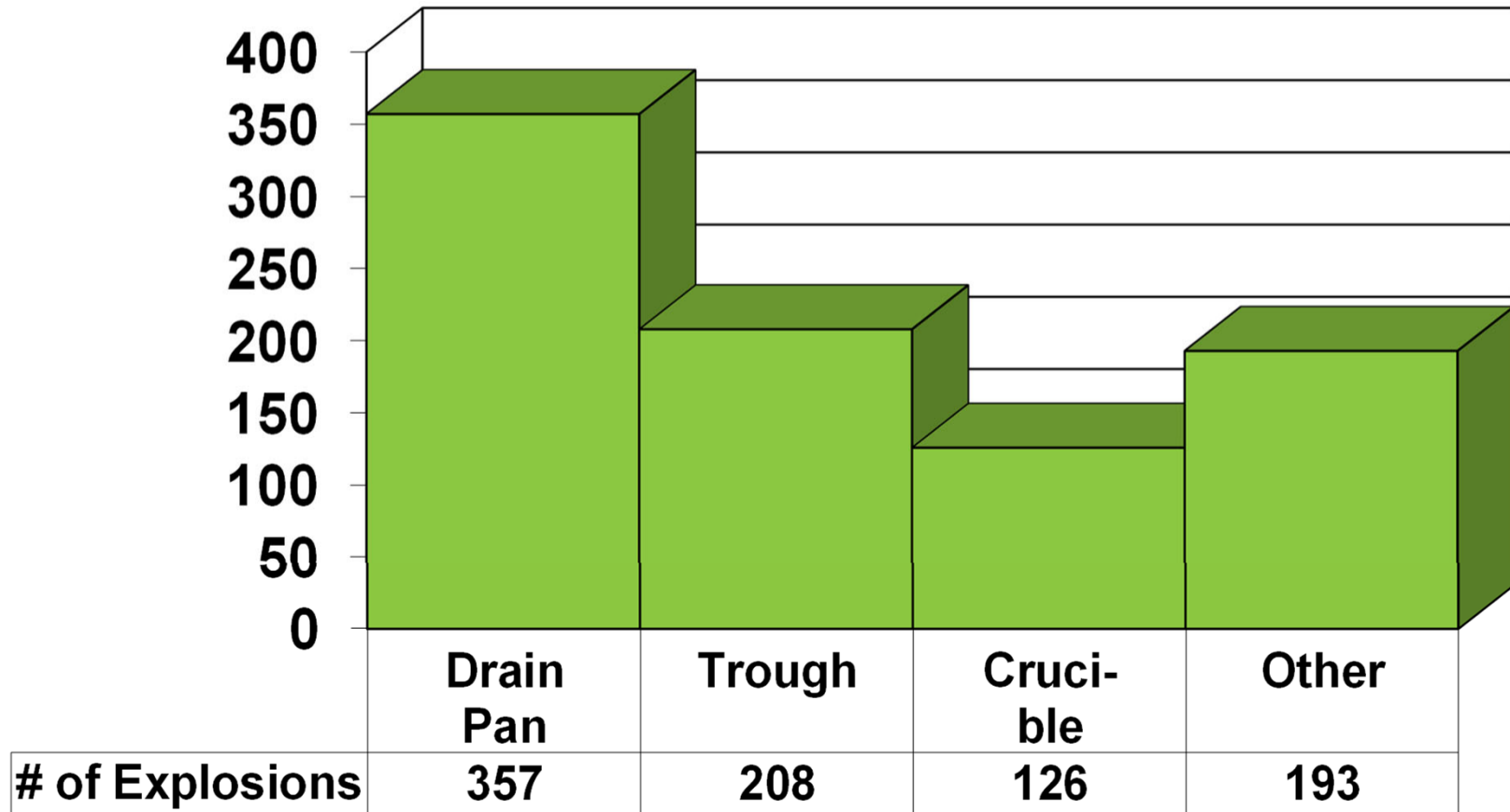


FIGURE 30. Transfer Explosions by Equipment 1980 – 2022 Sep. 2023



Major Causes of Transfer Explosions 2008 – 2022 (w/o 2011)

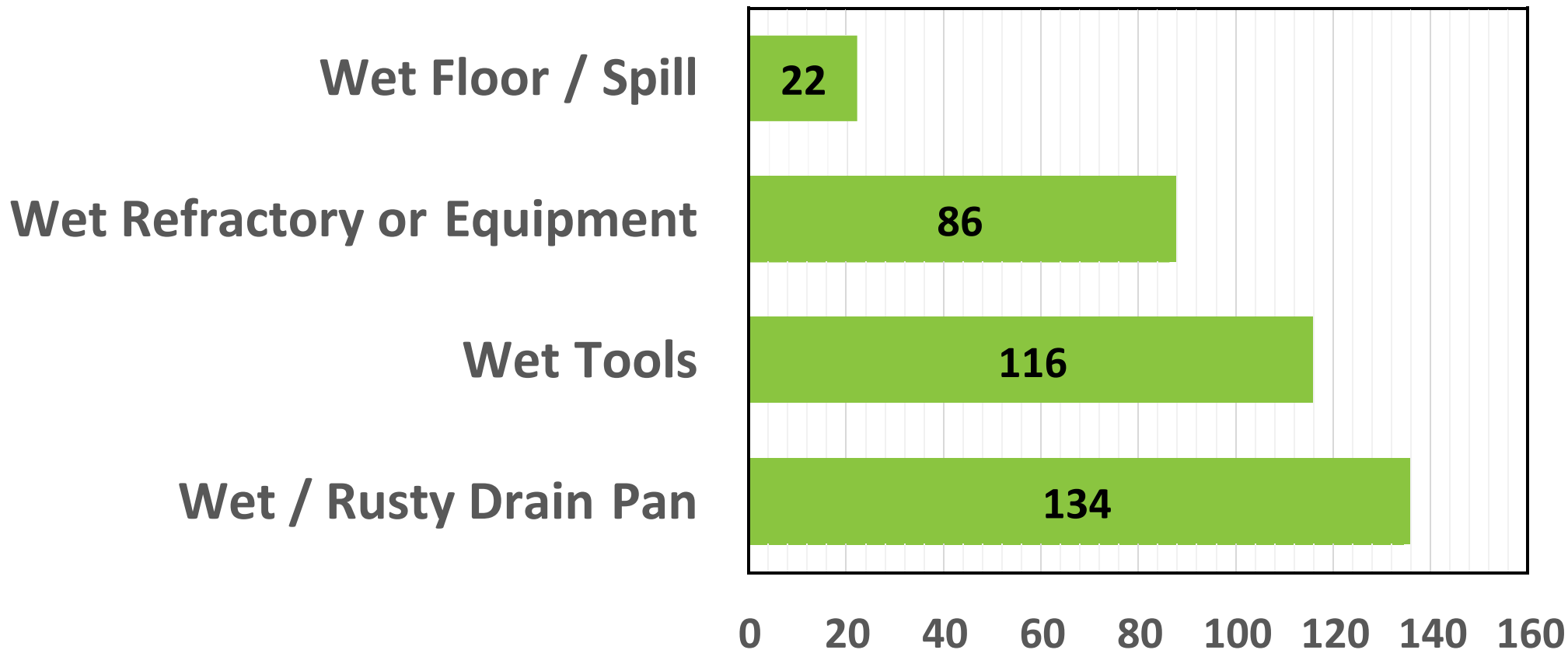


FIGURE 31. Transfer Explosions – Major Causes 2008 – 2022 Sep. 2023³³



Major Causes of Force 2 & 3 Transfer Explosions 2008 – 2022 (w/o 2011)

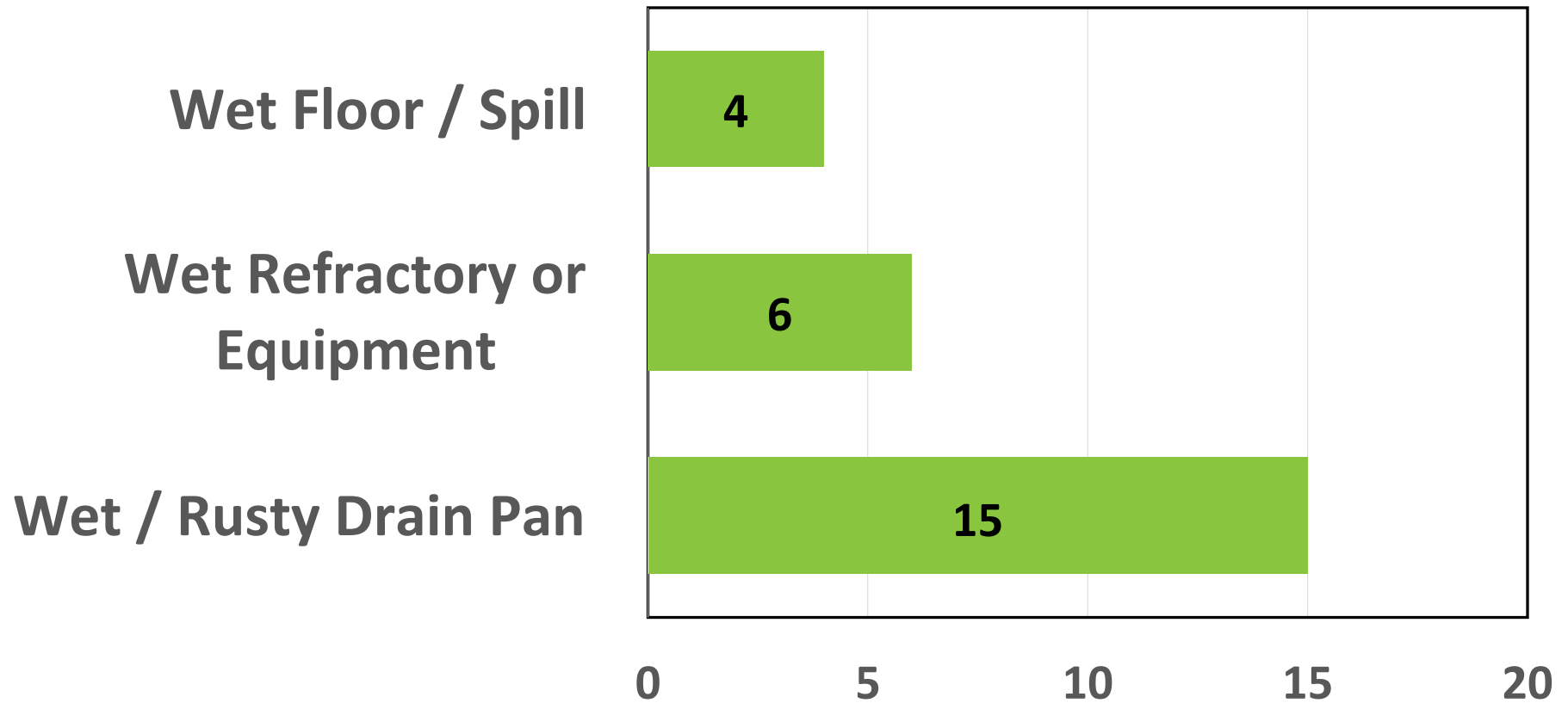


FIGURE 32. Transfer Explosions – Major Causes 2008 – 2022

Sep. 2023³⁴



13 Injuries by Operation – 2022

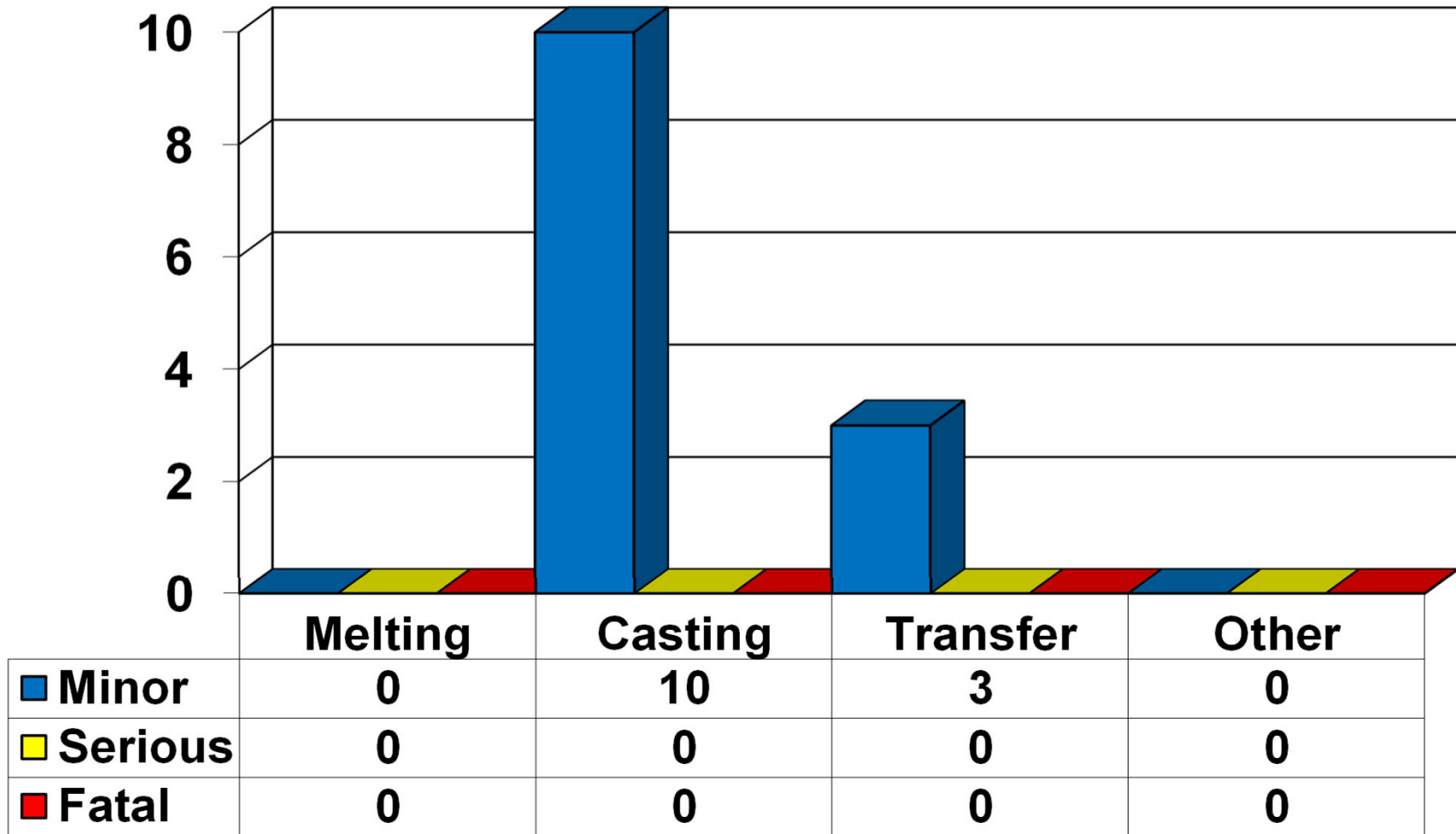


FIGURE 33. Injuries By Operation For 2022

Sep. 2023



1625 Injuries by Operation: 1980 – 2022

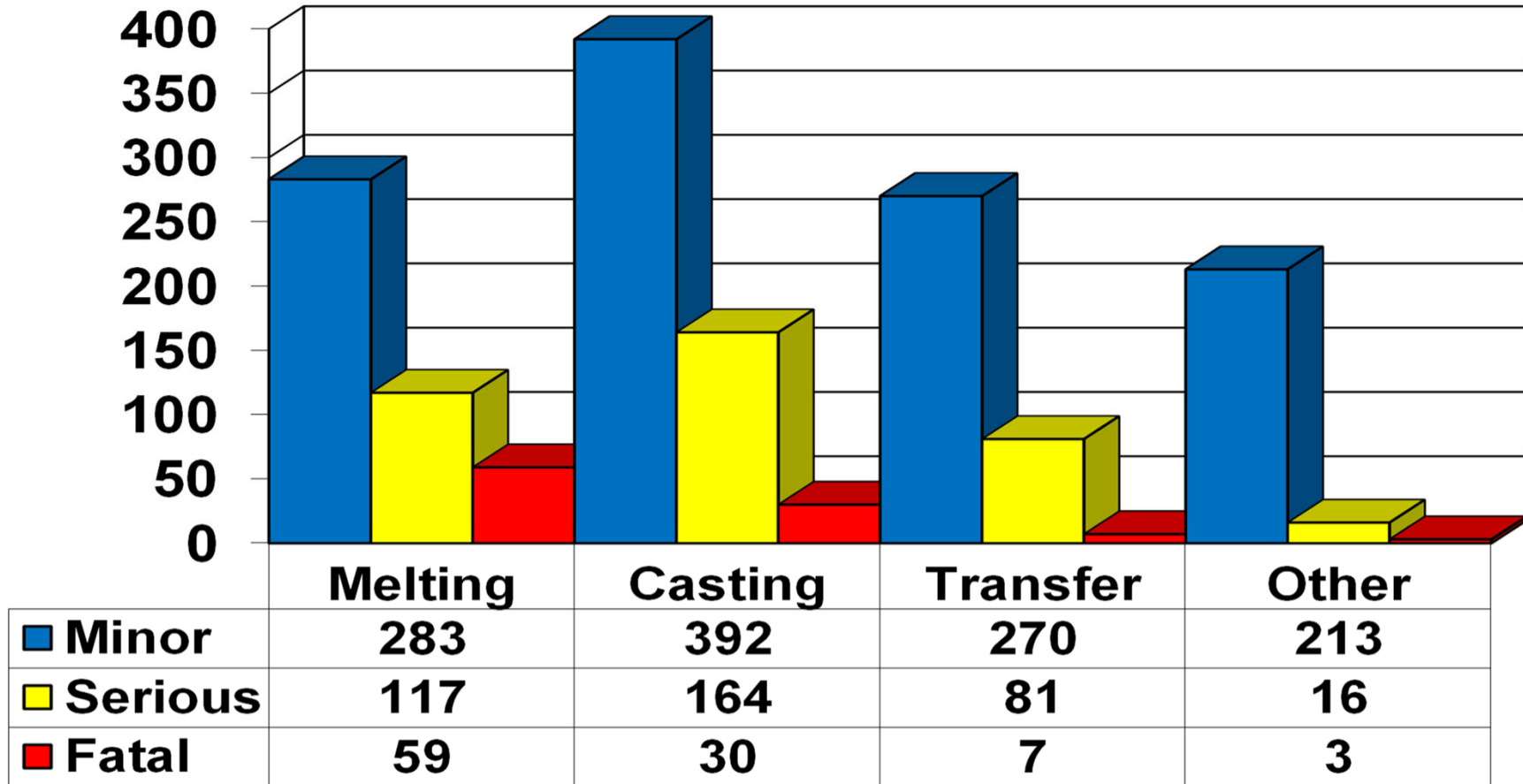


FIGURE 34. Injuries By Operation For 1980 – 2022 Sep. 2023



Melting Explosions By Month 2017 – 2022

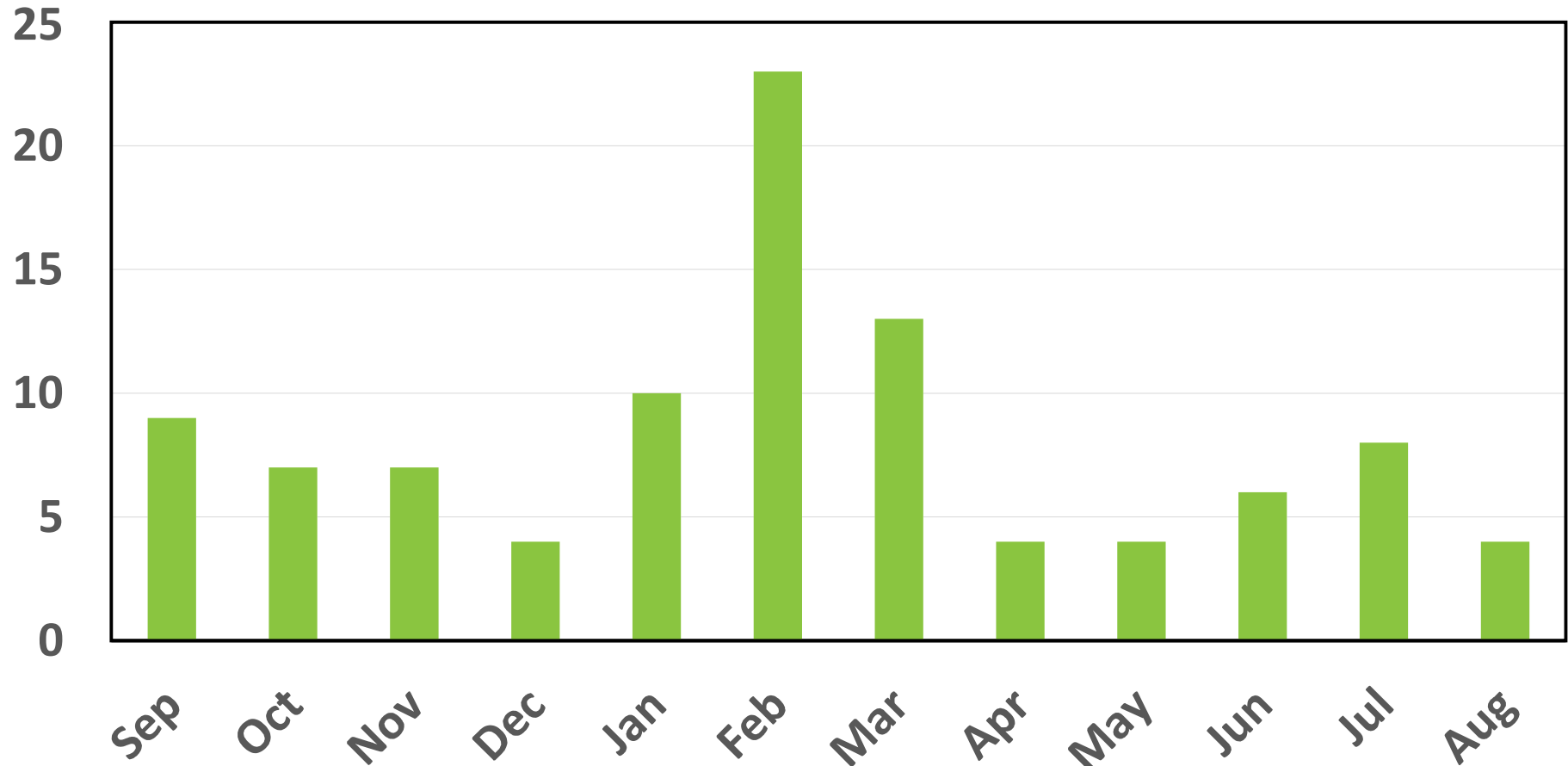


FIGURE 35. Melting Explosions By Month 2017 – 2022

Sep. 2023



Casting Explosions By Month 2017 – 2022

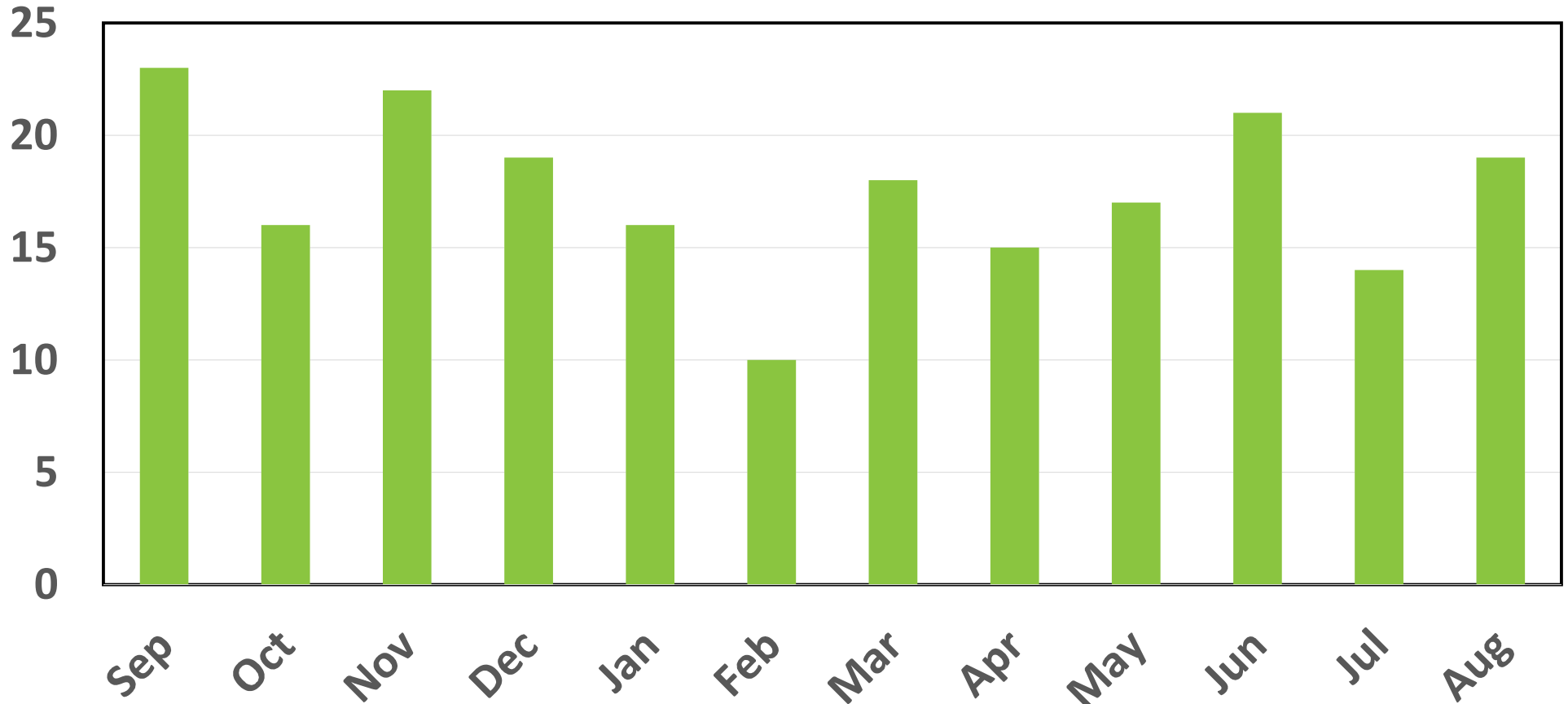


FIGURE 36. Casting Explosions By Month 2017 – 2022

Sep. 2023



Transfer Explosions By Month 2017 – 2022

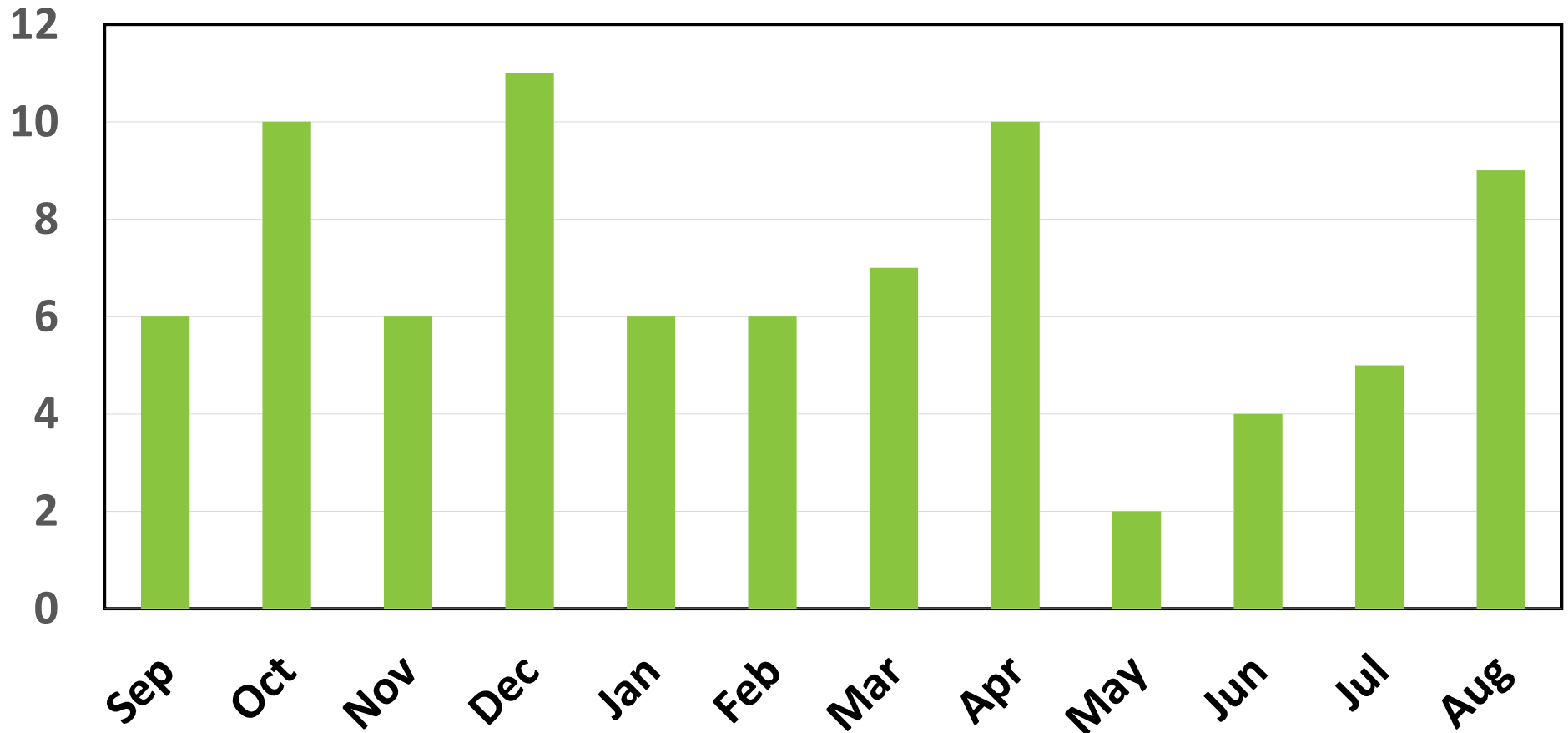


FIGURE 37. Transfer Explosions By Month 2017 – 2022

Sep. 2023



Force Level By Process Plant – 2022

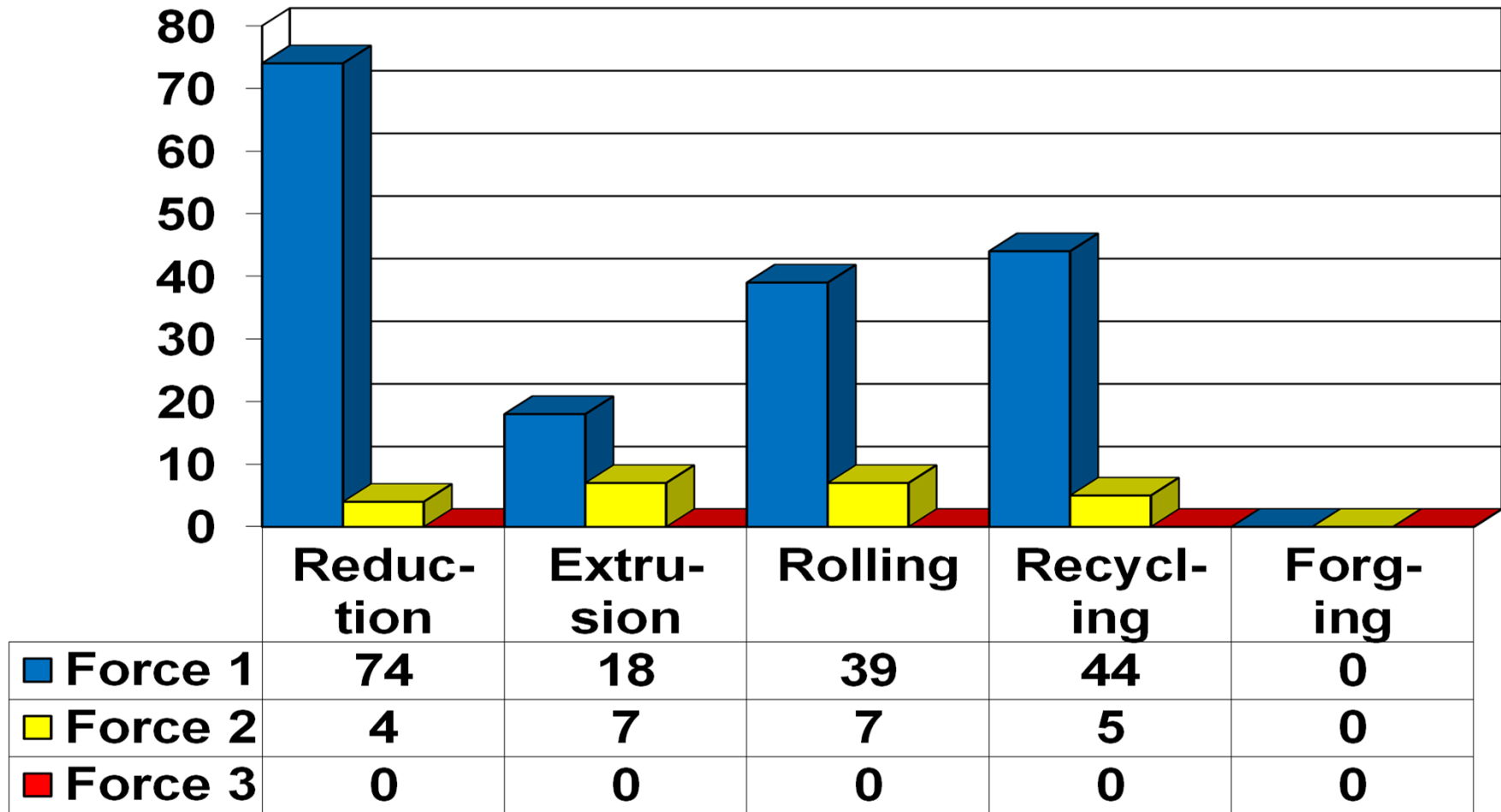


FIGURE 38. Force Level By Process Plant Reported For 2022 Sep. 2023



Force Level By Process Plant 1980 – 2022

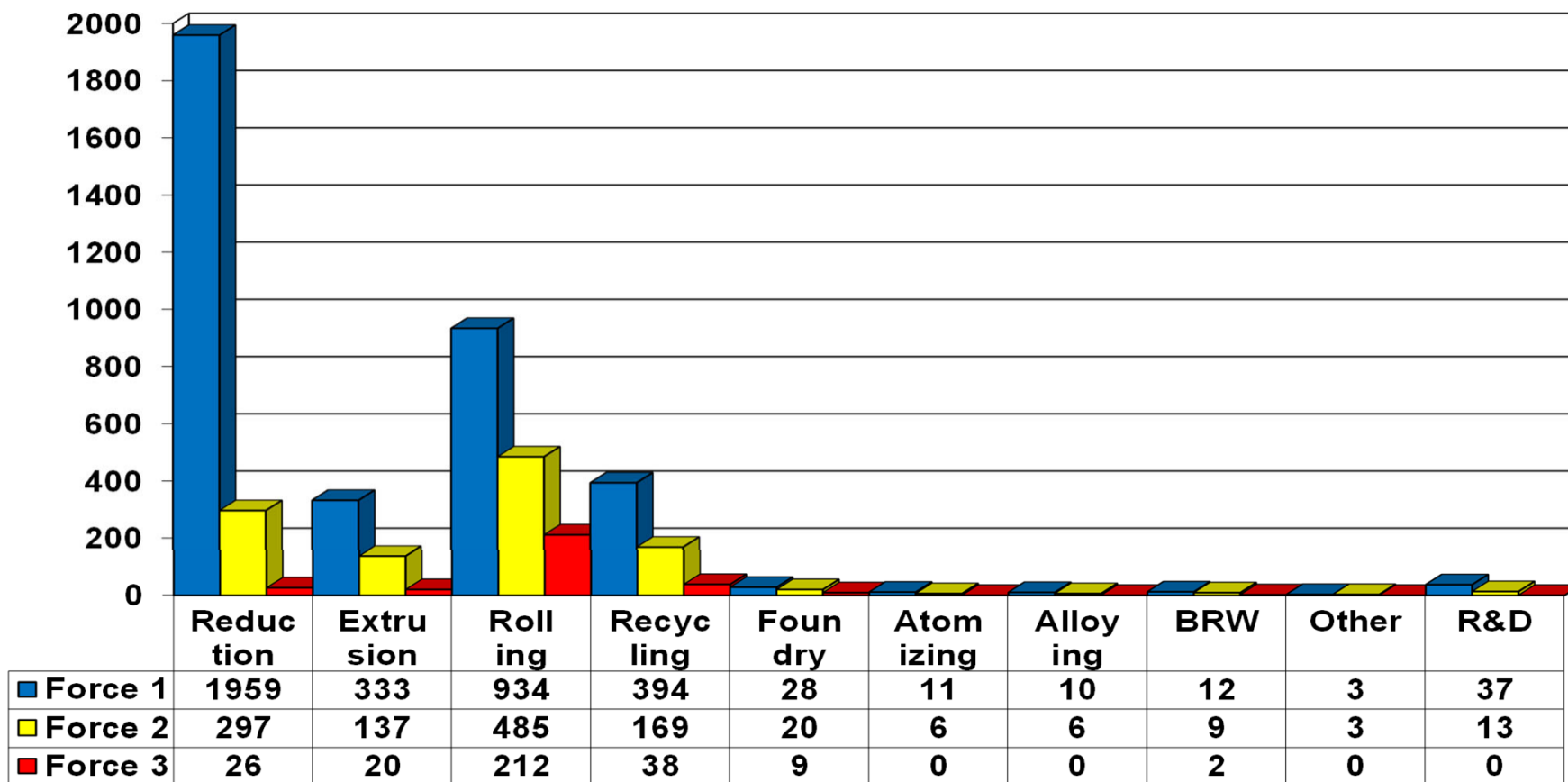


FIGURE 39. Force Level By Process Plant Reported For 1980 – 2022 Sep. 2023 

Reduction Plant

Main Causes of 79 Incidents – 2022

Melting Incidents	Casting Incidents
<p>2 – Wet Tool 1 - Wet Charge: Scrap / Sow 1 - Wet Mg</p>	<p>Sow Casting: 33 - Cracked, Wet or Rusty Molds 4 - Undocumented 3 - Wet Tool, Equip, Refractory 1 -Termination - Overflow on Wet Floor 1 - Thermite w/ Rust</p>
	<p>VDC – Billet & Slab 3 -Termination - Wet/Rusty Drain Pan 3 –Start-up – Wet Refractory / Equip. 2 - Termination - Overflow on Wet Floor 1 – Start-up – Wet Starting Block</p>

FIGURE 40. Reduction Plant Incidents Summary 2022

Sep. 2023



Reduction Plant

Main Causes of 79 Incidents – 2022

Transfer Incidents	Reduction Cell
<p>4 - Wet Tools & Equipment 2 – Wet / Rusty Drain Pan</p>	<p>4 – Wet Tools 3 - Tap-Out on Wet Floor 1 - Wet Tabular</p>
	<p>1 - Wet Tool 1 - Water Bottle</p>
	<p>1 - Anode into Wet Tub</p>
	<p>1 – Bath into Wet Tub</p>

FIGURE 41. Reduction Plant Incidents Summary 2022

Sep. 2023



Recycling Plant

Main Causes of 49 Incidents – 2022

Melting Incidents	Casting Incidents
<p>29 - Wet Charge: Scrap, RSI, Sow, Dross</p> <p>1 - Oxidized Mg</p>	<p>Sow Casting:</p> <p>3 - Wet or Rusty Molds</p> <p>4 - Wet Drain Pan</p>
<p>Transfer Incidents</p> <p>4 - Wet / Rusty Drain Pan</p> <p>3 - Wet Tools & Sample Mold</p>	<p>VDC – Billet:</p> <p>1 - Start-up – Wet Starting Block</p>

FIGURE 42. Recycling Plant Incidents Summary 2022

Sep. 2023



Reduction Plant Injuries & Incident Causes – 2022

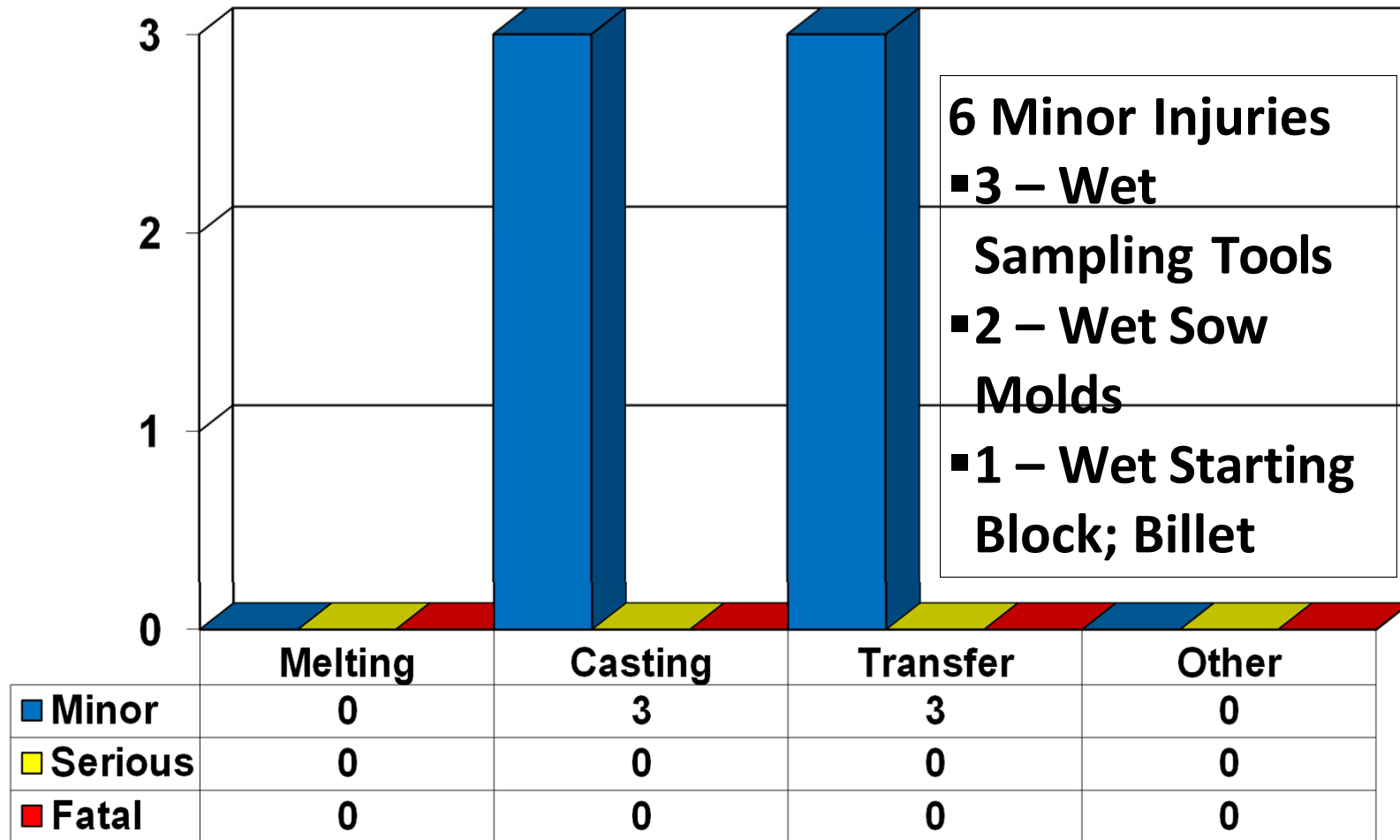


FIGURE 43. Reduction Plant Injuries By Operation 2022 Sep. 2023



Rolling Plant Injuries – 2022

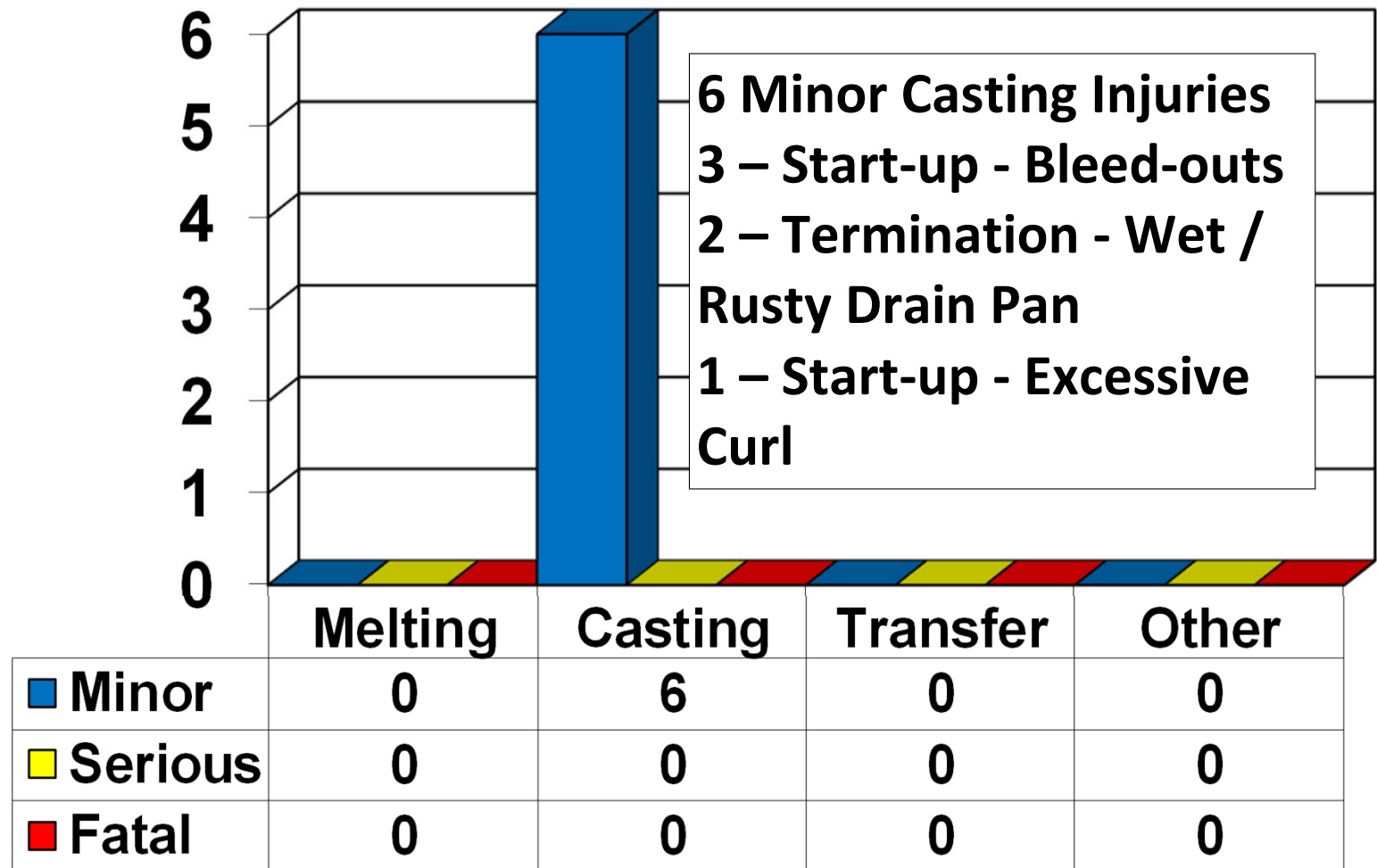


FIGURE 44. Rolling Plant Injuries By Operation 2022 Sep. 2023



Extrusion Plant Injuries – 2022

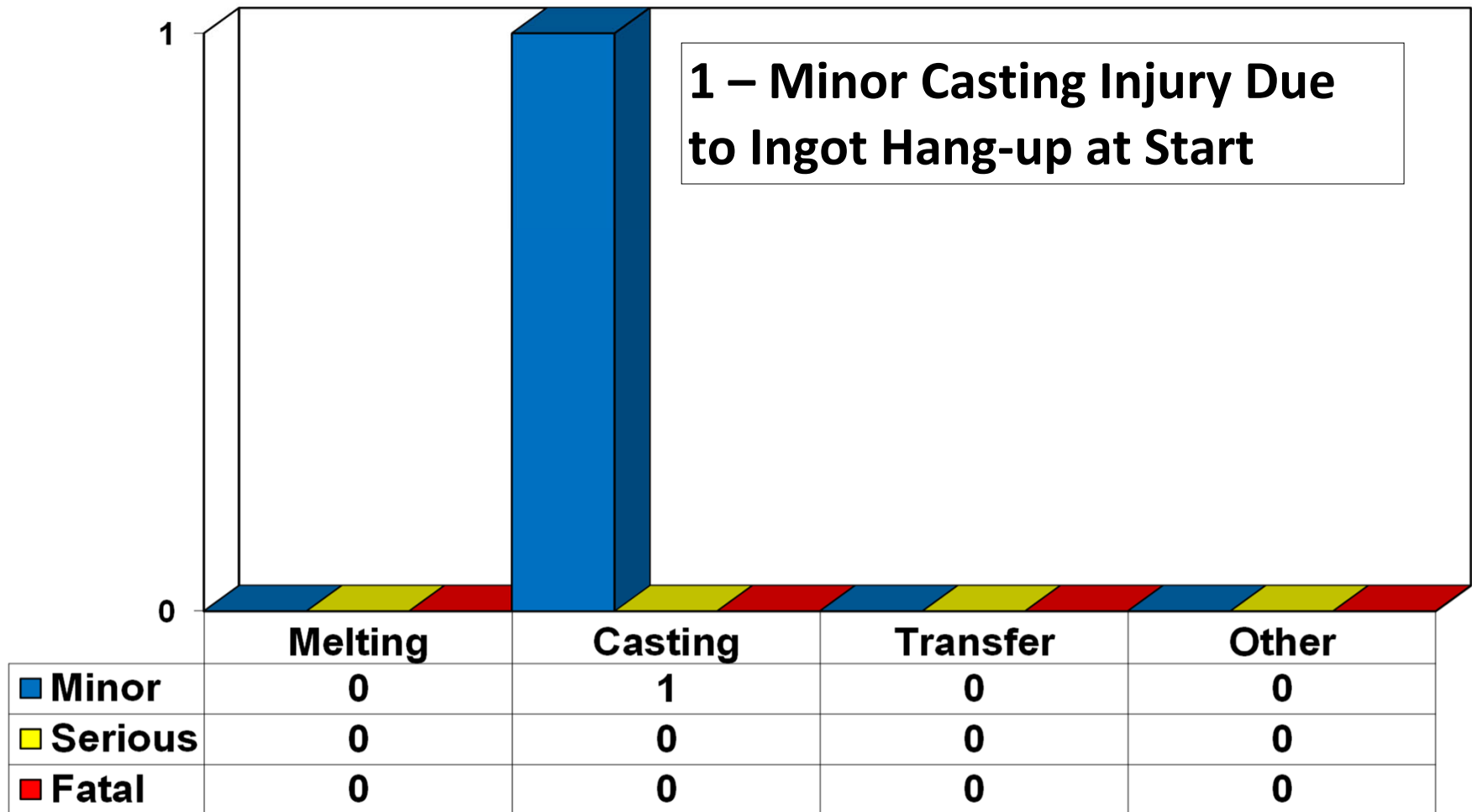


FIGURE 45. Extrusion Plant Injuries By Operation 2022 Sep. 2023



Recycling Plant Injuries – 2022

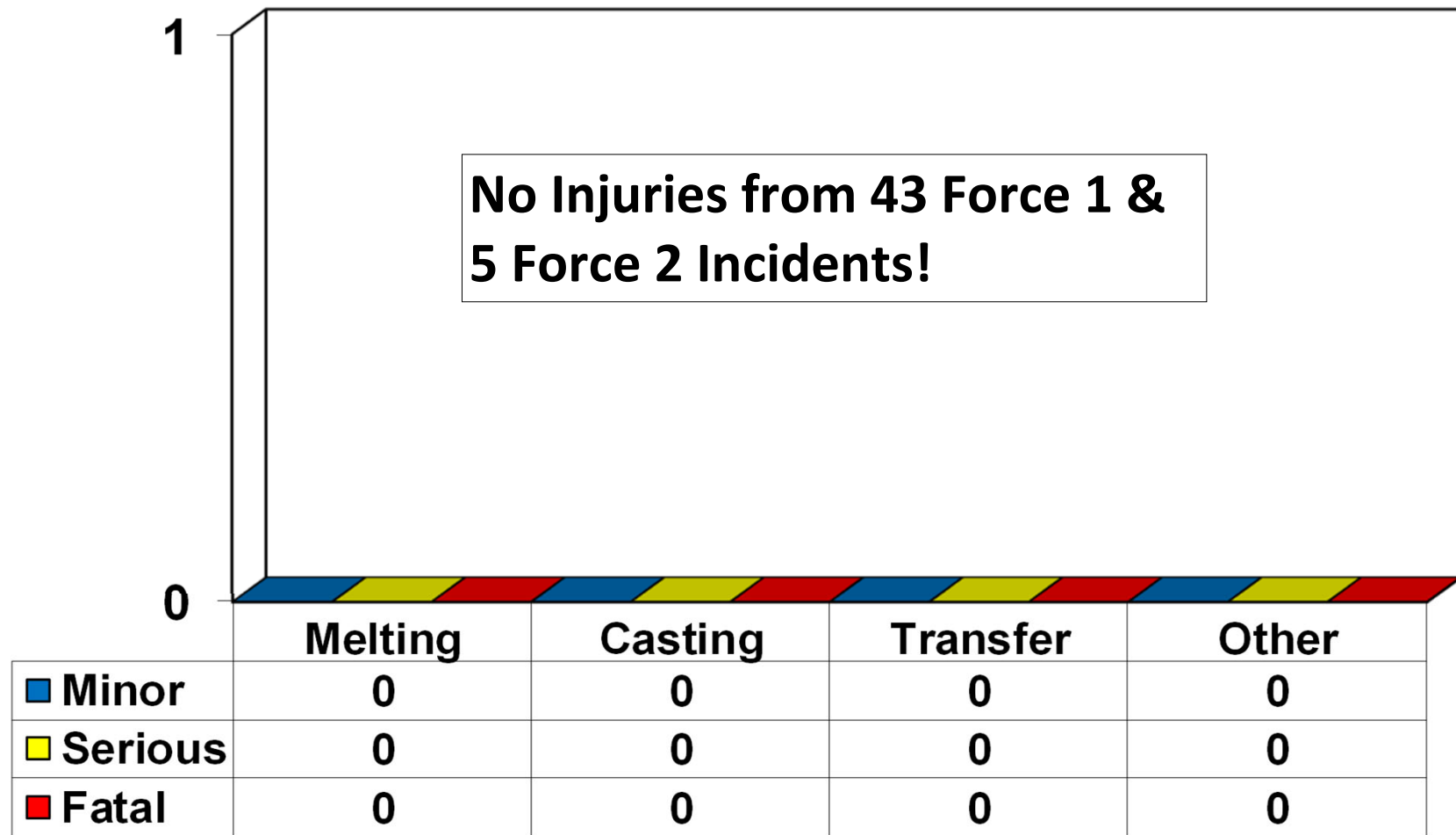


FIGURE 46. Recycling Plant Injuries By Operation 2022

Sep. 2023



Injury Severity by Process Plant – 2022

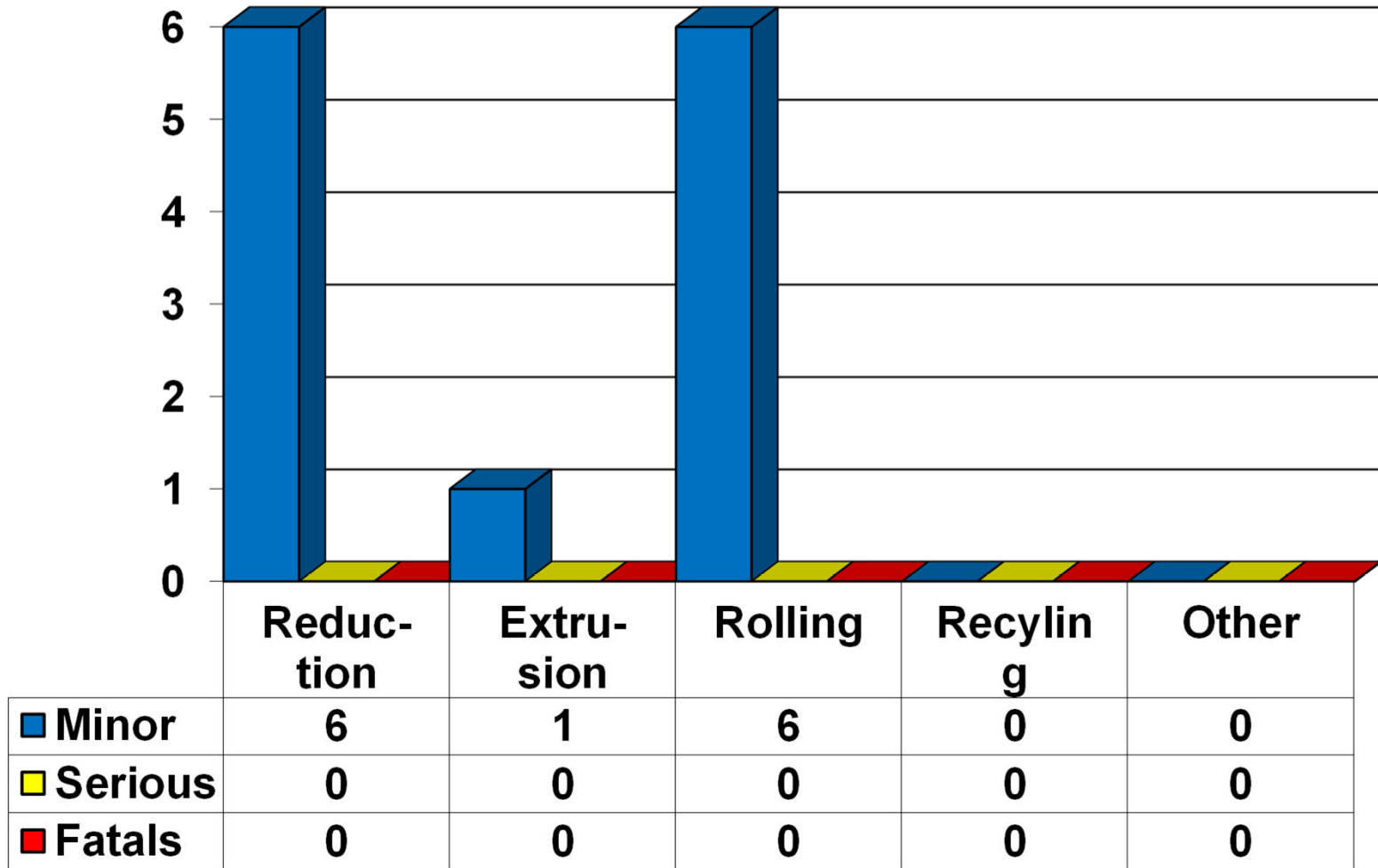


FIGURE 47. Injury Severity By Process Plant – 2022 Sep. 2023



Injury Severity by Process Plant 1980 – 2022

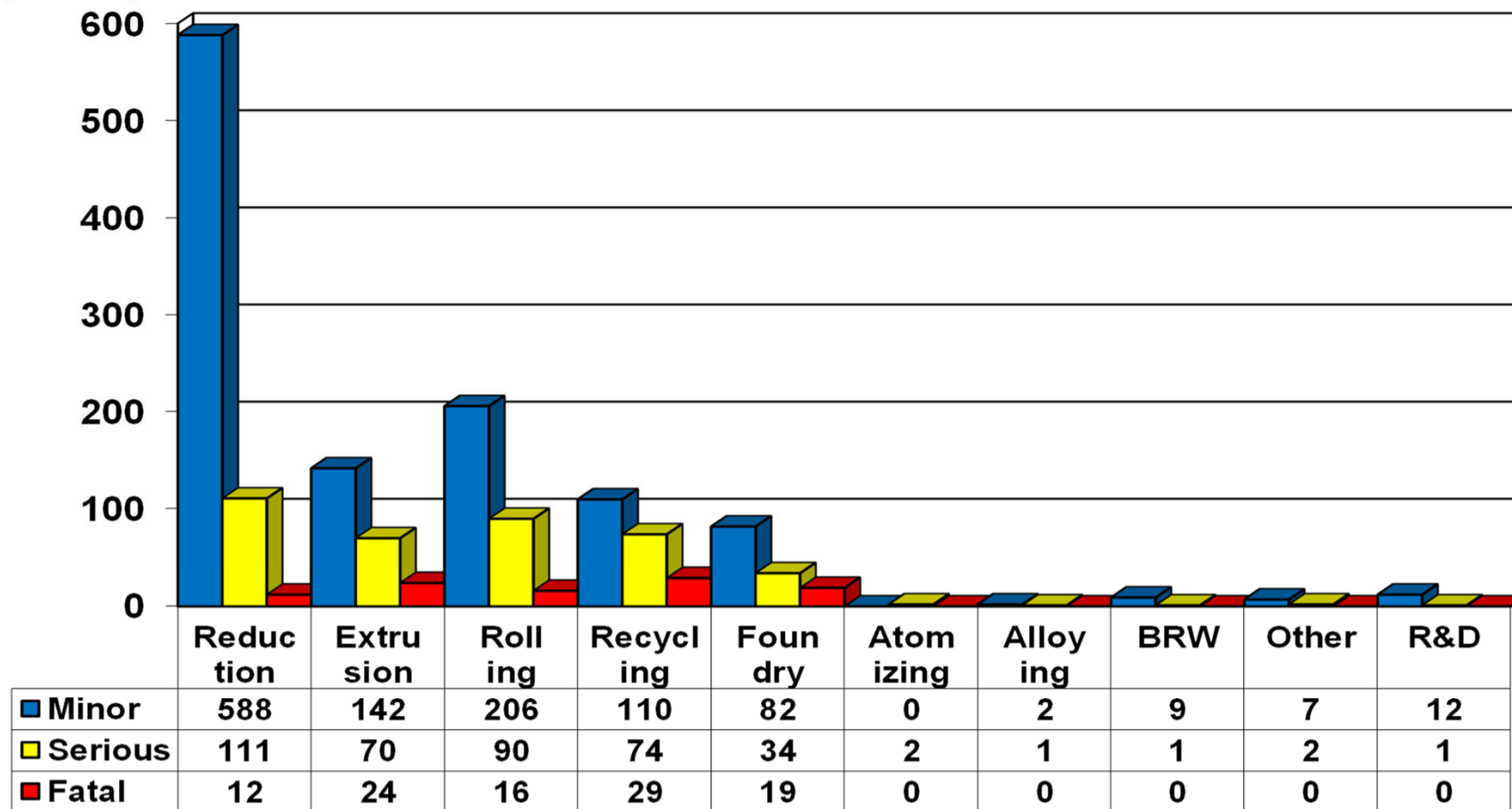


FIGURE 48. Injuries Severity By Plant Reported For 1980 – 2022 Sep. 2023



Reduction & Recycling Plant Incidents, Injuries / Incident Rate 2012 – 2022

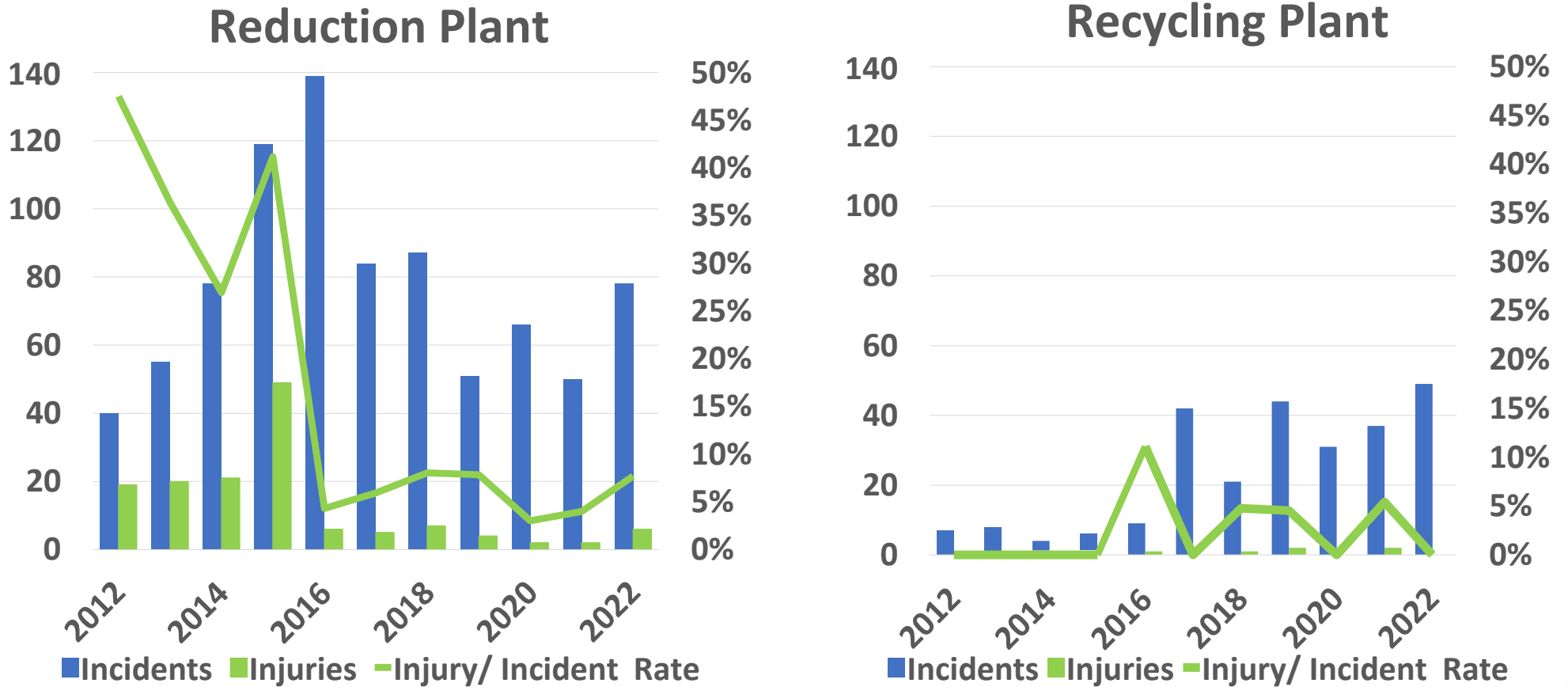


FIGURE 49. Reduction & Recycling Incident, Injury & Injury Rate 2012-2022 Sept. 2023₁



Rolling & Extrusion Plant Incidents, Injuries / Incident Rate 2012 – 2022

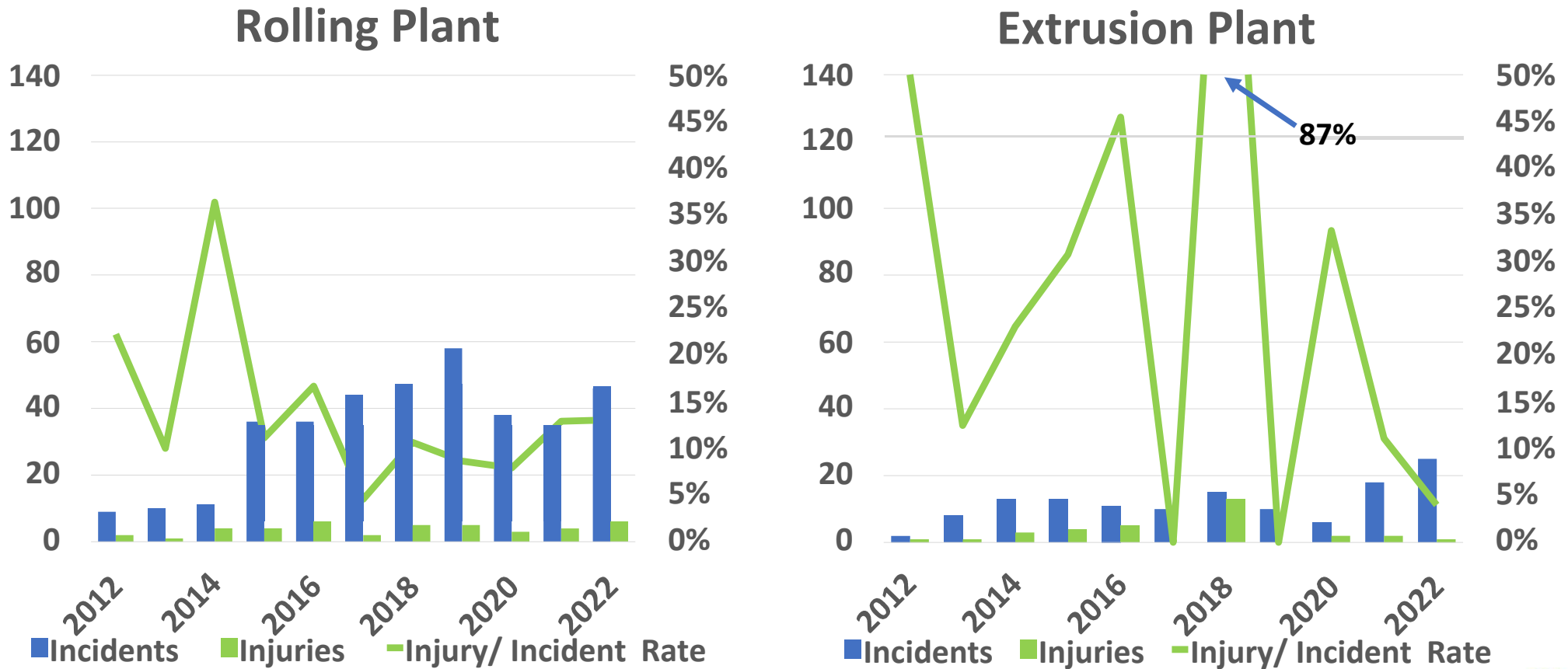


FIGURE 50. Rolling & Extrusion Incident, Injury & Injury Rate 2012-2022 Sept. 2023 52



