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The Aluminum Association

ANNUAL SUMMARY REPORT ON MOLTEN METAL INCIDENTS FOR 2021

September 2022

For the year **2021**, **140** molten metal incident reports occurring world-wide were received as compared to **147** reports received for **2020** and **166** reports for **2019**. The attached figures summarize the reports for 2021 as well as the data for the years 1980 thru 2021.

SUMMARY POINTS:

- **For 2021, there were 140 explosion incidents reported, which continued the downward trend in reported incidents over the previous 4 years. The 2021 total incidents are lower than the historically high number of incidents (170 – 195) reported between 2016 and 2018.**
- **There were 116 Force 1 explosions, 23 Force 2 explosions and one Force 3 explosion reported in 2021. Compared to 2020, Force 2 explosions increased from 12 to 23, while the Force 1 explosions decreased from 134 to 116. One Force 3 incident has been reported each of the last three years.**
- **There has been a notable increase in Force 2 explosions over the past 6 years starting in 2016 with an average of 21/yr., which reversed a downward trend that was observed starting around 2008 and continued through 2014.**
- **Of note, there were no reported fatalities in 2021, as well as 2019 and 2020 and 2015 through 2017. There have been 99 reported fatalities for the entire length of the program, starting in 1981.**
- **Over the past 10 years there were only two years with Fatalities: 2014 with one and 2018 with 8, which involved two major Casting incidents. The 0.9/yr. average fatality rate for the past 10 years is significantly lower than the 2.4 annual rate for the entire length of the program.**
- **Reported injuries increased slightly to 10 (9 Minor & one Serious) from the 2020 record low of only 7 Minor injuries.**
- **Also of note, 7 of the 10 injuries, including the one Serious injury, were related to 5 casting Termination explosions and wet / rusty drain pans. 4 of the 5 explosions were Force 2 explosions with only one being a Force 1.**
- **Of high significance, the data shows a sharp decrease in injuries starting in 2016 compared to historical values. When comparing average amount of injuries/year for the years 2001-2015 vs. 2016-2021, the latter timeframe is significantly lower (16.8 vs. 48.1 injuries/yr.) for all categories: Minor, Serious and Fatal. For these last 6 years, the**

average Fatal / Yr. were 30% lower, average Serious / Yr. were 58% lower, average Minor / Yr. were 68% lower and average Total injuries / Yr. were 65% lower.

- **Of 59 Casting incidents, 46 (42 Force 1 and 4 Force 2) were related to Start-up, 13 (7 Force 1 and 6 Force 2) occurred during Termination. 7 of the 13 Termination explosions involved wet / rusty drain pans. There were no Steady State explosions, which is highly unusual.**
- **There were no injuries reported from any of the 55 Melting explosions. There were 12 Force 2 Melting explosions and one Force 3. All but one of these 12 Force 2 & Force 3 explosions were related to wet / contaminated scrap, sow, RSI or alloy materials. One Force 2 involved furnace overflow onto a wet floor.**
- **There were two Minor injuries reported from 22 Transfer incidents. Wet hand and furnace tools or wet equipment were involved in 13 of the explosions and 6 involved wet / rusty drain or skim pans.**
- **Force 2 and 3 Transfer incident data from 2008 through 2011 indicate that wet / rusty drain pans cause almost 3 times the number of incidents compared to the next leading cause of wet refractory / equipment.**
- **For 2021, 13 of 77 (17%) Casting and Transfer explosions were related to wet / rusty drain pans.**
- **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 new charts added to the 2020 report.**
- **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.**
- **2015 and 2018 are two years in the past 10 that stand out with a high numbers of injuries: 1) one 2015 Force 3 Melting explosions with 35 minor injuries; and 2) two 2018 Force 3 casting explosions with 25 injuries, including 8 fatalities.**
- **New analysis and charts were added displaying incidents per month for the three categories of Melting, Casting and Transfer. The Melting data indicated a higher incident rate in the northern hemisphere "winter months" of January, February and March, most likely related to the higher potential for charging materials to be contaminated with water, snow and ice.**

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

Table 1: Explosion Rating Force Criteria

	LOW		SEVERE
Guidelines			
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 thru 2021 the total number of reported incidents, **4339**. The **140** explosions reported in 2020 continue a downward trend over the past four years, but still in the same higher range of an increased reporting level starting in 2015. There has been an average of 166 incidents/year reported over the past 7 years, compared to an average of 145 incidents/year from 2000 through 2007 and 83 incidents/year from 2008 through 2014.

Figures 2 thru 6 provide **Force Level** data for the years 1981 thru 2021 in various formats, including the number of incidents and rates. **Figure 2** displays the reported incidents each year for all three Force Levels. In 2021 there were **116 Force 1**, **23 Force 2** and **one Force 3** explosions. Compared to 2020, Force 2 explosions increased from 12 to 23, while the Force 1 explosions decreased from 134 to 116. The last three years all had one Force 3 explosion reported.

Figure 3 shows the data for only **Force Levels 2 and 3** and **Figure 4** displays only **Force Level 3**. Both **Figure 3 and Figure 4** include the average number of explosions per year for this time frame. From 2008 through 2021 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 5 and 10 years (1.0/yr. and 0.8/yr. respectively) continues to show a much lower level compared to the 2.8/yr. average for the entire reporting history from 1981 through to 2021. 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 2021 with an average of **21/yr.** over the past 6 years.

Comparing the number of **Force 2 Melting** vs. **Casting** explosions for the last 6 years, they both had equal amounts, **56**. This is atypical of historic data where **Force 2** explosions occurred in **Melting** by a wide margin. The balance of the Force 2 incident occurred almost equally in **Transfer** (7) and **Other** (6).

Figures 5 and 6 display a comparison of all three **Force Levels** for the entire reporting history from 1981 through 2021 in two different formats: 1) bar graph and 2) pie-chart. **Force 1** incidents account for **76.3%** of all incidents, up slightly from 2019 and 2020 which were at **75.6% and 76.1%** respectively. The **Force 2** and **Force 3** incident rate in 2021 both lowered slightly compared to 2020 from **21.0%** to **20.9%** and from **2.9%** to **2.8%** respectively.

Figures 7 thru 12 provide in various formats of injury incident data (**Minor, Serious and Fatal**) for the years 1981 thru 2021. The **Figure 7** bar chart shows **Minor, Serious and Fatal** injuries for each year. In 2021 there was a total of 10 injuries, **Zero Fatalities**, **one Serious** and **9 Minor.** This was a slight increase from the 2020 record low of only **7 Minor** injuries**.**

There have been **99** reported **Fatalities** for the entire length of the program, starting in 1981. Over the past 10 years there were only two years with **Fatalities**: 2014 with **one** and 2018 with **8**, which involved two **Force 3 Casting** incidents. The **0.9/yr.** average **Fatality** rate for the past 10 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. A reduction in injuries for the past 6 years is displayed more clearly in **Figure 8**, which is a chart started two years go for the 2020 Summary report. When comparing average injuries/year for the years 2001-2015 vs. 2016-2021, the latter timeframe is significantly lower for all categories of injury: **Minor**, **Serious** and **Fatal**. For these last 6 years, the average **Fatal** / Yr. were 30% lower, average **Serious** / Yr. were 58% lower, average **Minor** / Yr. were 68% lower and average **Total** injuries / Yr. were 65% lower. And this data includes the two 2018 **Force** 3 explosions with **12** injuries **(8 Fatalities, 2 Serious and 2 Minor).**

From 1981 through 2021, there is now a total of **1615 Minor, Serious and Fatal** reported injuries with **Figure 9** showing the total injuries in these three categories. The **Figure 10** pie chart breaks this down into percentages: **70.0% Minor**, **23.9% Serious** and **6.1% Fatal**.

Figure 11 presents the likelihood of no injury per 100 incidents vs. the likelihood of an injury in each injury category. This indicates that for each 100 incidents reported there is a **26.1%** rate for **Minor** injuries, an **8.9%** rate for **Serious** injuries and a **2.3%** rate of a **Fatality** vs. a **62.8%** rate of **No Injury**. All three of these injury rates decreased in 2021 vs. 2020 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 data if all explosions were reported, but this does provide an indication of the potential rate of an injury per incident.

Figure 12 displays data only related to **Fatalities** for the entire reporting program from 1981 through 2021. There have been **9 fatalities** over the past 10 years, with 8 of the 10 reported in 2018, as previously noted, due to the **two Force 3** casting explosions. The **0.9/yr.** average fatality rate for the **past 10 years** is significantly lower than the **2.41** annual rate for the entire length of the program.

Figures 13 thru 46 provide more detailed information regarding the **140** reported explosions in **2021** along with similar charts comparing this yearly data with the entire database from 1980 thru 2021. 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 15-20**); and 2) Summaries of the major causes of **Casting and Transfer** incidents over recent years (**Figures 26, 27, 30 & 31**).

Figure 13 shows the 2021 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 thru 2021 in **Figure 14**. In 2021, most explosions occurred in **Casting (59)**, with **Melting (55)** slightly lower; **Transfer (22)** and **Other (4)** being the lowest as usual. All **Other** explosions occurred in the **Reduction** Process. The **23 Force 2** incidents in 2021 is an increase compared to the **12** in 2020, but in-line with recent years. **Melting** and **Casting** had similar numbers of **Force 2** incidents, **12** and **10** respectively.

The lone **Force 3** explosion reported in 2021 was during a **Melting** operation in a **Recycling** plant and was related to wet scrap. Approximately 1000kg (2200lbs.) of metal was ejected from the furnace. There were no injuries because of the explosion.

Most **Force 2** and **Force 3** explosions for the entire reporting period continues to be related to the **Melting** operation by a wide margin as shown in **Figure 14**.

As reported in previous years and shown and discussed above when reviewing **Figures 7** and **8**, there is a general decrease in the number of injuries, especially when comparing the last 6 years to the previous 15 years. **Figures 15** through **20** 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 up-swing in incidents in the early 2000's and a higher incident volume for the last 7 years. There is downward trend over the last 5 years after a peak in 2016, as is seen previously in **Figures 1** and **2**. In contrast, however, there appears to be a downward trend in **Injuries per Incident or Injury Rate** over the last 7 to 10 years. A downward trend can be observed especially for the **Casting** and **Transfer** operations (**Figures 18** and **20**). **Melting injuries** and **Injury Rate** have been very low for the last 10 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 the **Injury per Incident Rate** charts (**Figures 16, 18 and 20**) a best fit line is provided along with R^2 values, which are very low due to the scatter in the data. It is an obviously 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 improvement with primary and secondary PPE materials, design and use, movement toward 'hands-free' casting removing personnel from the casting pit during cast starts, and increased training and hazard awareness.

Figure 21 provides 2021 data regarding the type of charge materials involved in **55 Melting** incidents, the same number as reported in 2020. The leading cause of the explosions (**43** of the **55**) was wet scrap, sows and RSI. Wet alloy material (Mg and Si) accounted for **9** explosions, **one** being **Force 2**. There were **12 Force 2 Melting** explosions and **one Force 3**. All but one of these **13 Force 2** and **Force 3** explosions were related to wet / contaminated scrap, sow, RSI or alloy materials. **One Force 2** involved furnace overflow onto a wet floor.

A compilation of the **Melting** explosion data over the years 1980 thru 2021 for the various types of charging materials involved is shown in **Figure 22**. 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. 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 23 provides a breakdown of the **59 Casting** incidents in 2021 in two different ways: by stage in the process and by type of casting process. There were **10 Force 2** and **0 Force 3** explosions in 2021. As typically seen in the past, most of the explosions occurred during **Start-up (46),** with **4** being **Force 2**. At cast **Termination** there were **13** explosions, with **6** of the **13** being **Force 2**. Wet / rusty drain pans was the cause of 7 of the **13** explosions with **4** being **Force 2** incidents. There were **zero Steady-State** incidents, which is very unusual.

DC Billet or Slab accounted for **29** of the **Casting** incidents, with **27** occurred when casting **Sows** or **Molds.** Most **Force 2** explosions **(7** of **10)** occurred during **DC Billet or Slab** casting.

Figure 24 shows **DC Casting** incidents by drop segment for years 1980 - 2021. The historical data is similar to the 2021 data shown in **Figure 23** in that most explosions occur during **Start-up**. For the first time, the **End-of Cast** explosions now outnumber the total **Steady-State** explosions**.**

For 2021, **Figure 25** provides the major causes of the **59 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 and bleed-overs, equipment set-up and hang-up and release. The main DC casting termination issues were wet / rusty drain

pan, wet tool and trough overflow. The main sow and mold casting incidents were due to wet or cracked molds, and wet equipment or tools.

Figures 26 and **27** were new charts started in 2021 that provide additional analysis of the primary causes of **Casting** explosions, looking at the last 7 years of data, **2015** through **2021**. **Figure 26** shows the major causes for all Force levels, while **Figure 27** is data for only **Force 2** and **3 Casting** explosions. By a large margin, the reason for most **Casting** explosions at all **Force** levels is wet, cracked or rusty sow molds. This is followed by excessive curl / hang-up / bleed-out explosions during DC cast starts, which is also the highest cause if segregating for **Force 2** and **3** incidents only, **14** in total for these 7 years. Due to the high number of **Force 2** wet /rusty drain pan **Termination** explosions in 2021, there are now **12 Force 2** and **3** incidents for this reason. These are followed by wet, cracked or rusty sow molds (**8**).

There were **22 Transfer** explosions (**21 Force 1** and **1 Force 2**) in 2021, as shown in **Figure 13. Figure 28** shows that the majority of these incidents were the result of two issues. Wet hand and furnace tools or equipment accounted for **13** of the incidents. Wet or rusty drain pans or molds totaled **6**.

Figure 29 provides a bar chart showing the equipment involved in **862 Transfer** explosions for the years 1980 thru 2021. The highest number of **Transfer** explosions are related to **Drain Pans**, followed by **Trough** and then **Other**.

Like **Figures 26** and **27** presented above for **Casting**, **Figures 30** and **31** were first presented in 2021, providing further detail regarding the major causes of **Transfer** explosions. **Figure 30** provides the data regarding the major causes of all **Transfer** explosions for the years **2008** through **2021** (excluding 2011), while **Figure 31** provides this information for only **Force 2** & **3** explosions. The highest cause of explosions is wet / rusty drain pan (**89** incidents); however wet refractory or equipment (**86** incidents) is very nearly the same. It should be noted in the **Force 2** & **3** data, that wet / rusty drain pans cause almost 3 times the number of incidents compared to the next leading cause of wet refractory / equipment.

When combining **Casting** and **Transfer** incident data for wet / rusty drain pan, this source of explosions accounts for 17% (13 of 77) of the 2021 explosions in these two categories.

Injuries by **Operation** (**Melting, Casting, Transfer and Other**) resulting from the 140 explosions in 2021 is provided in **Figure 32**. **Casting** accounted for **8** of the **10 injuries**, with one being **Serious** and the balance **Minor.** The **two Transfer injuries** were both **Minor.**

Figure 33 provides **Injury** by **Operation** data for 1980 thru 2021. The highest number of **Minor** and **Serious** injuries has occurred in the **Casting Operation**. The **Melting Operation** accounts for the highest number of **Fatalities,** also the highest number of **Force 3** explosions as seen in **Figure**

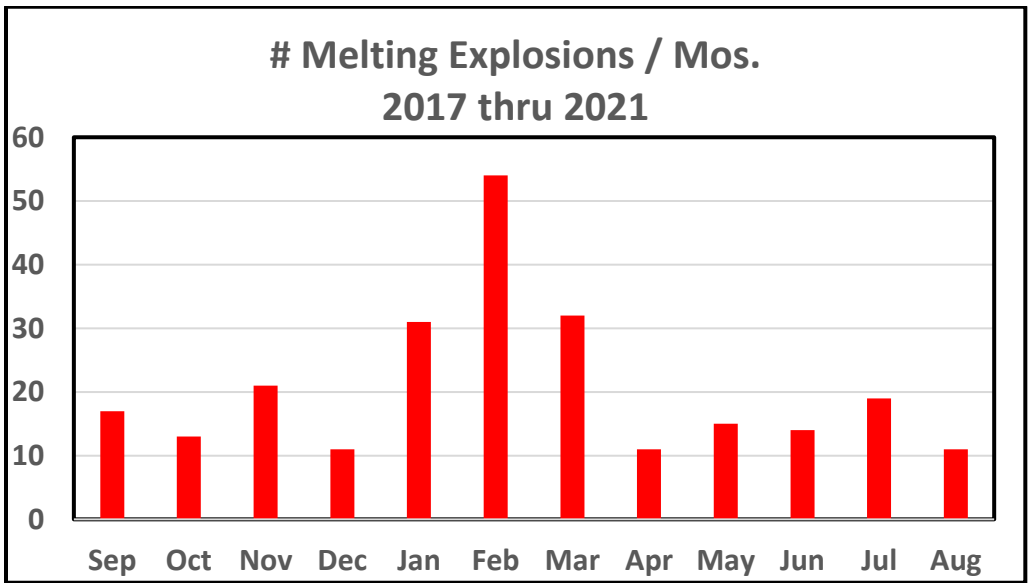
14. It should be noted that a significant number of injuries have occurred in rather straight forward **Transfer Operations**, including **81 Serious** and **7 Fatalities.**

As noted above, the highest number of **Fatalities** and **Force 3** explosions occur during **Melting Operations**. Additional data analysis was performed investigating if there was a correlation between the "time of year" vs. the number of incidents. **Chart 1** below (**Figure 34**) provides this **Melting** incident data for the last five years (2017 thru 2021). All causes of melting incidents were part of the analysis, which primary included wet or contaminated charge materials and wet equipment and tools.

This chart is presented starting in September through August, rather than in the traditional January through December format. This is to better emphasize a higher incident rate in the northern hemisphere "winter months" of January through February when there is a higher potential for winter weather of snow, ice and rain to contaminate scrap and sows. With this explanation of higher incidents at this time of year it may be anticipated that November and December would also so show an increase. November does show a slight increase compared to August and September; however, December is decidedly lower. This result may be explained in that during December there can be more maintenance and holiday shutdowns / slowdowns that can occur in this month.

This data may be worthwhile sharing with plant personnel to emphasize the need for increased emphasis and attention to storage, drying and charging procedures at this time of year, which may have relaxed during the summer months.

Chart 1



Incident frequency by month is also provided in Charts 2 & 3 below (**Figures 35 & 36**) 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. And December does not show the same lower frequency as was observed in the Melting data.

It should be noted that the incident database used for these charts does not include month of the year 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.

Chart 2

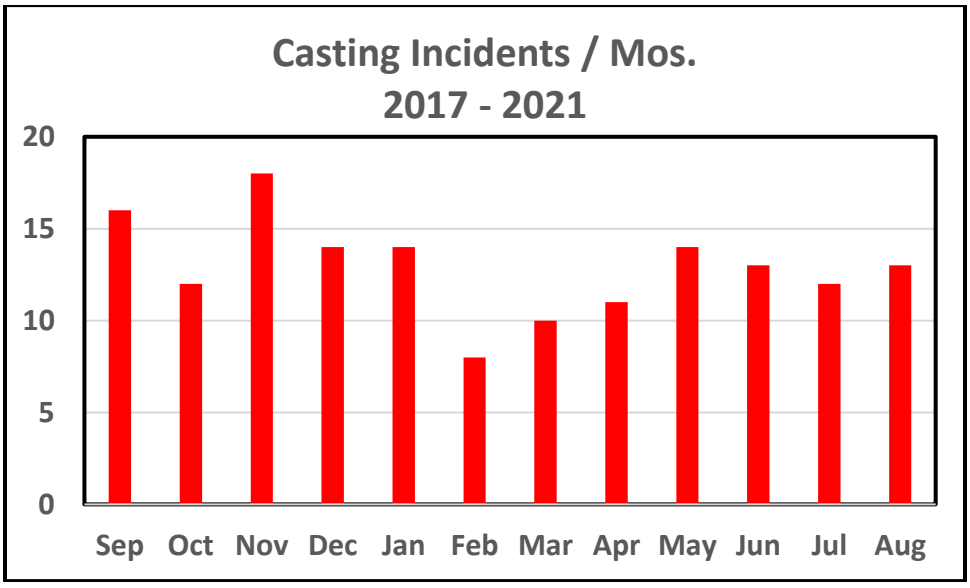
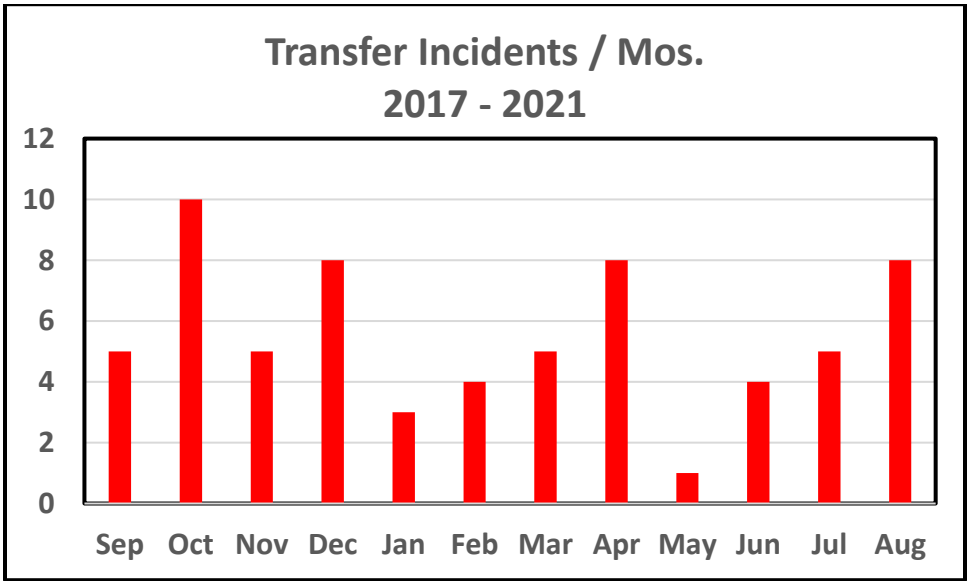


Chart 3



Figures 37 and **38** provide incident data vs. the type of **Process Plant** (**Reduction, Extrusion, Rolling** and **Recycling**) for 2021 and for 1980 thru 2021 respectively.

In 2021, the highest number of incidents occurred in **Reduction** Operations (**50**), compared to the next highest **Recycling** Operations (**37**). **Recycling** also reported the highest number of **Force 2** incidents (**8**) and the **one Force 3** incident. **Extrusion** was next highest with **7 Force 2** incidents, followed by **Rolling** (**5**) and **Reduction** (**2**). **Figure 35** provides corresponding data for the entire reporting period, 1980 thru 2021. The highest number of incidents occurring in **Reduction** and the second highest reported from **Rolling**, which by far has reported highest number of **Force 3** explosions.

The main causes of the 2021 **Reduction** facility explosions are presented in **Figures 39** and **40.** They are listed by **Melting**, **Casting** and **Transfer / Reduction** incidents. **Melting** incidents were related to wet charge materials. The primary reason in **Casting** was cracked, wet or rusty molds for sow casting. **Transfer** and **Reduction** incidents were primarily related to wet / rusty equipment, tools and drain pans.

Figure 41 is a bar chart providing **Reduction** plant injury information for the **two Minor** Injuries in 2021. There were no Serious Injuries. The **two** injuries were both **Transfer** related to wet / unpreheated hand tools.

Rolling plant **Injury** information is provided in **Figure 42**, with all **4** occurring in **Casting**, **3 Minor** and **one Serious**. **Three** of the **4** injuries, including the **one Serious,** were the result of wet / rusty drain pans.

For **Extrusion, Figure 43**, there was only one **Minor** injury, due to a wet/ rusty drain pan.

There was one **Recycling Force 2** incident, **Figure 44**, which resulted in both injuries in this category, and it was also due to a wet/ rusty drain pan.

Figure 45 summarizes the 2021 injury data by type of **Process Plant** and **Figure 46** shows this same data for 1980 thru 2021.

The last page of the report after the Figures provides an Aluminum Association Molten Metal Incident Report Form or you can link to the form at:

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

R T Richter – September 20, 2022

The Aluminum Association

Incidents by Year
1981 to 2021 Total 4339

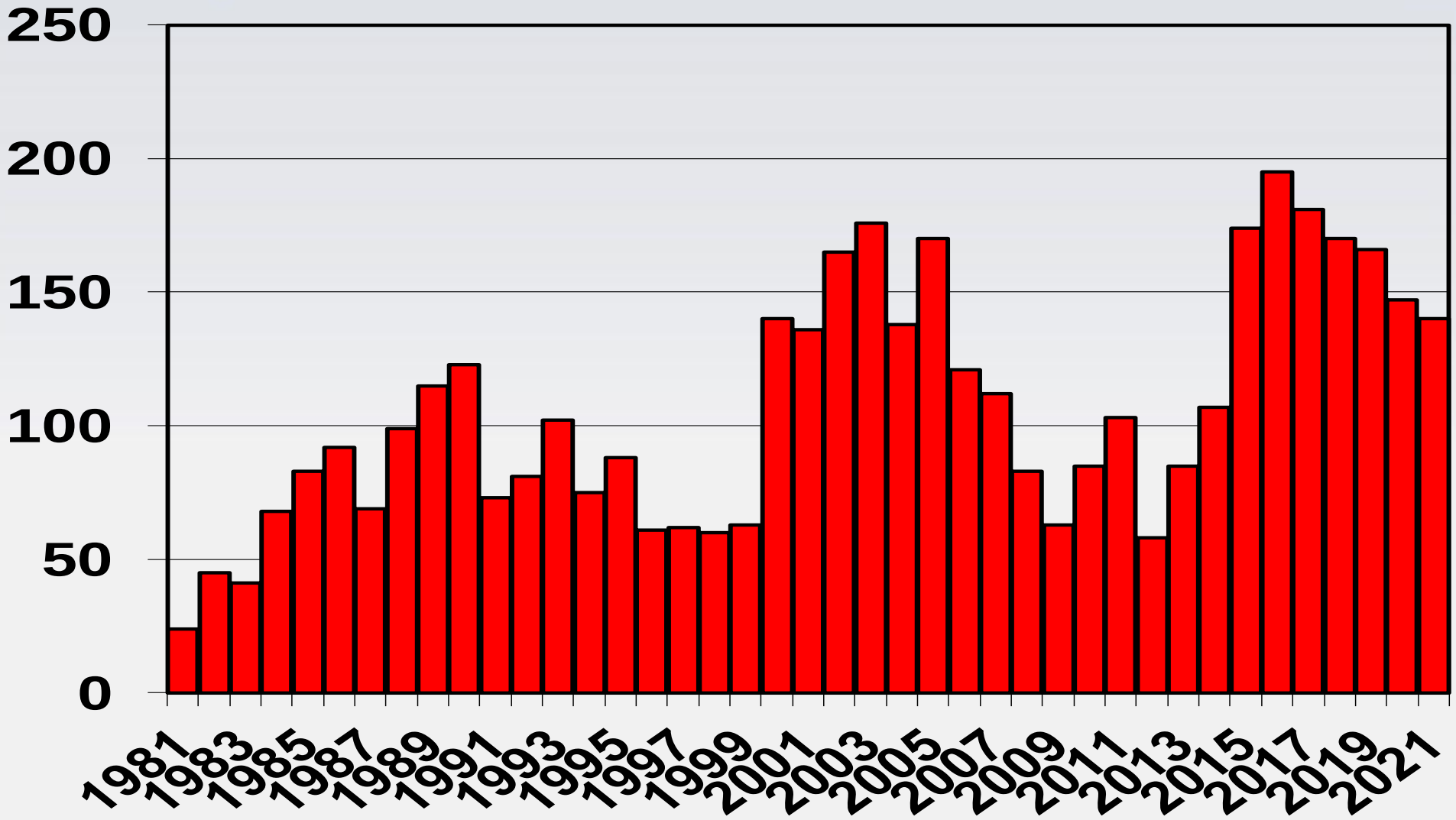
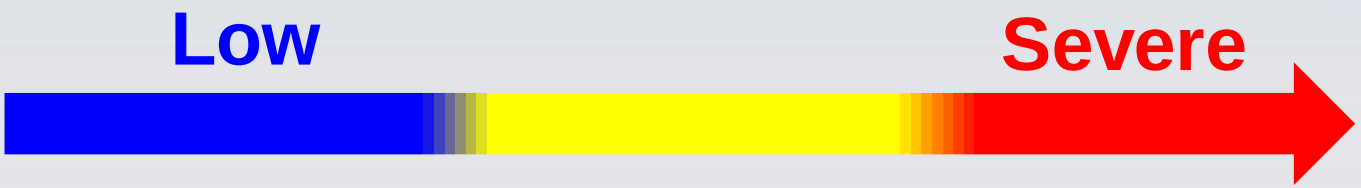


FIGURE 1. INCIDENTS REPORTED FOR THE PERIOD 1981 – 2021 Sep. 2022

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. 2022**

Incidents by Force Level
1981 to 2021 – Total 4339

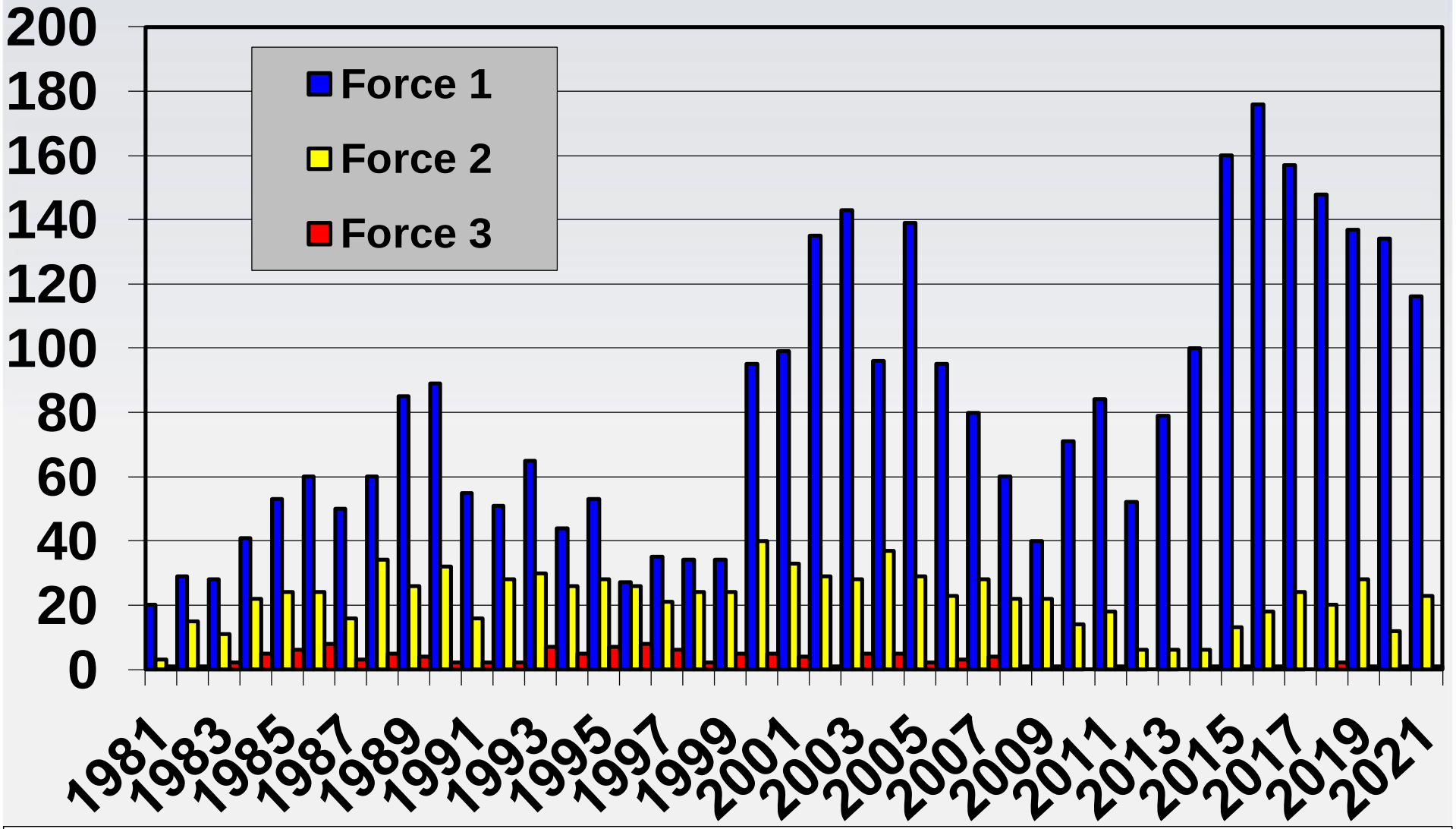


FIGURE 2. INCIDENTS BY FORCE LEVEL FOR 1981 – 2021 **Sep. 2022**

Incidents by Force Levels 2 & 3
1981 to 2021

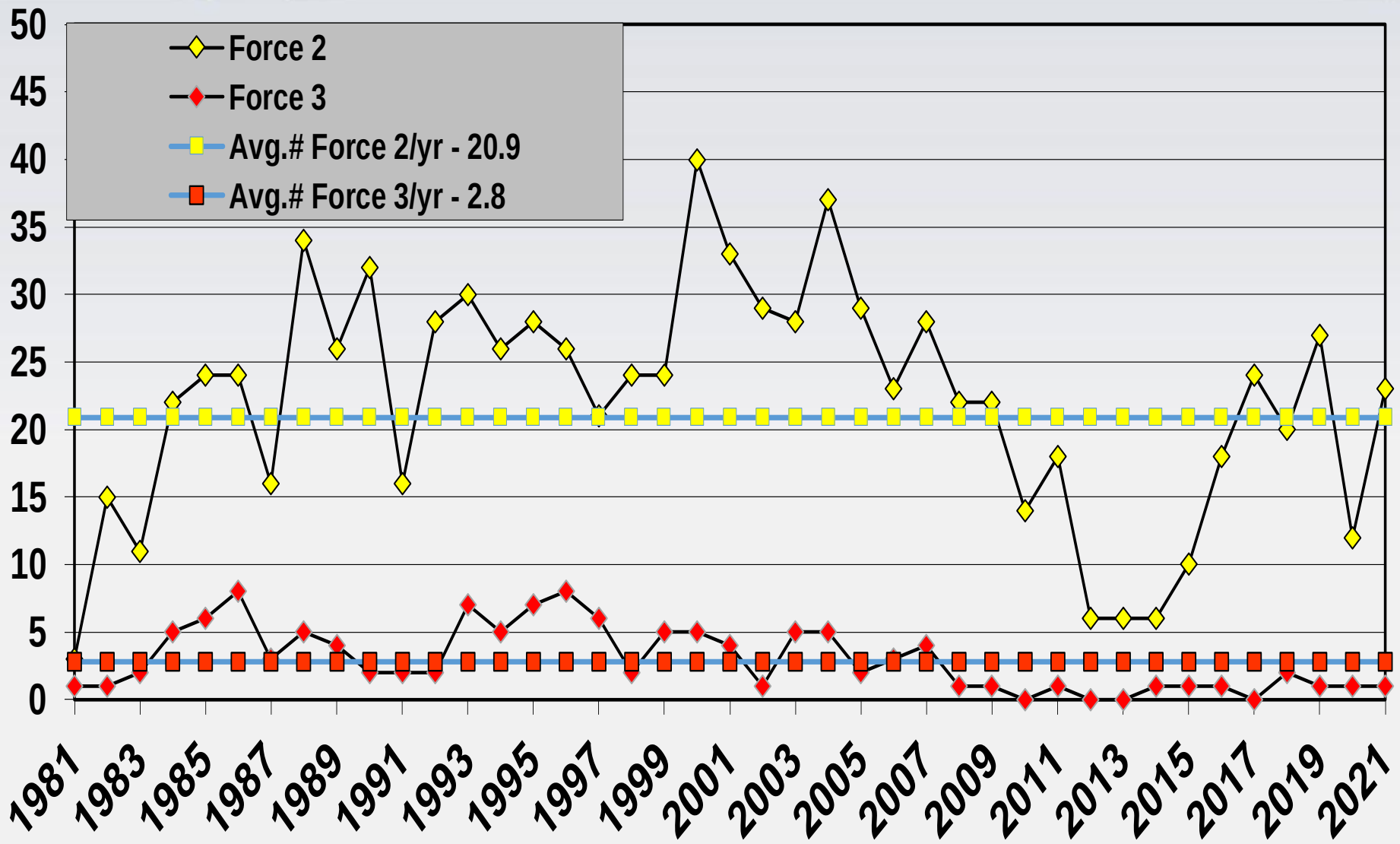


FIGURE 3. INCIDENTS BY FORCE LEVELS 2 & 3 FOR 1981 – 2021 Sep. 2022

Force 3 Incidents Only
1981 to 2021

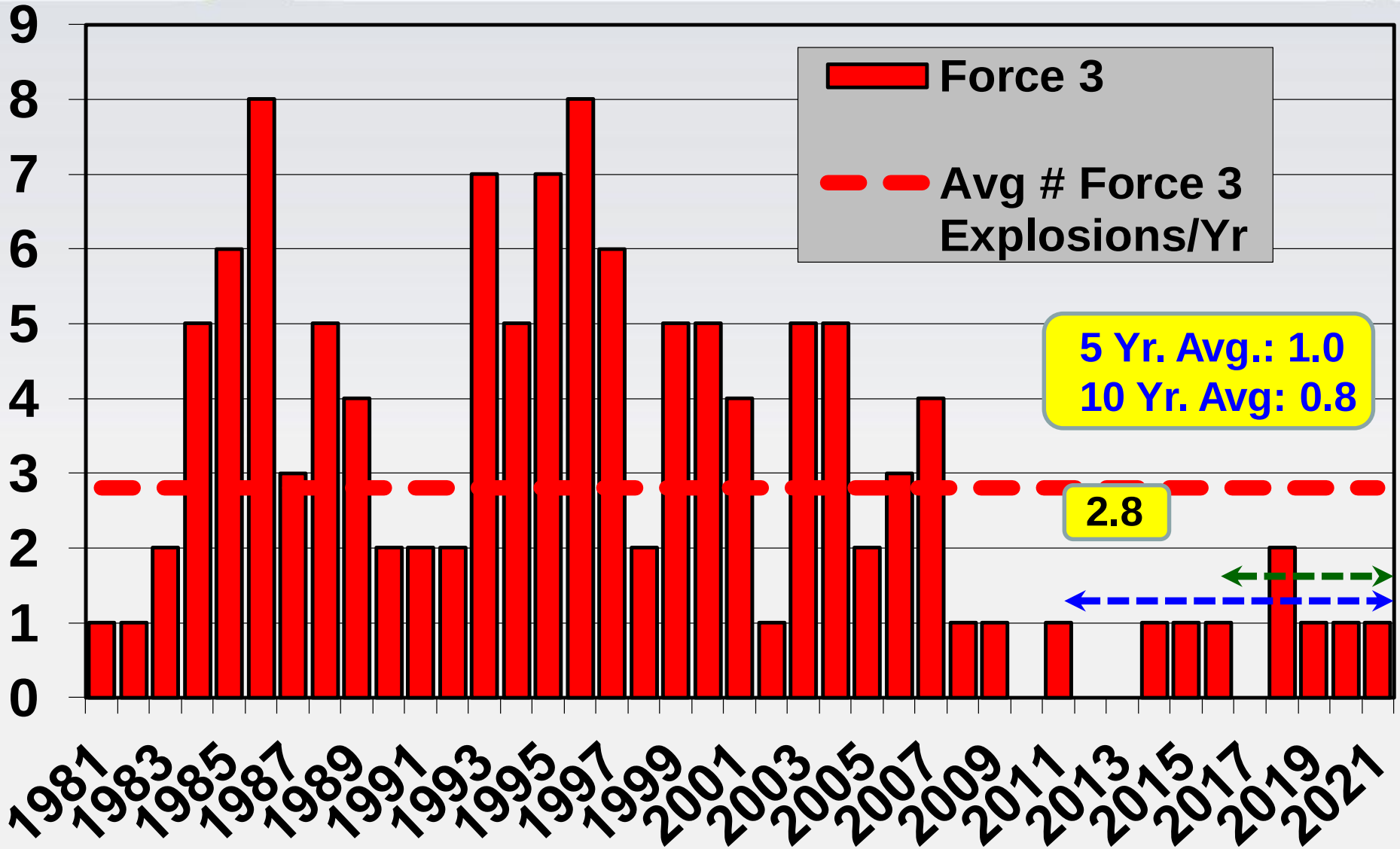


FIGURE 4. FORCE 3 INCIDENTS FOR 1981 – 2021 Sep. 2022

Incidents by Force Level
1981 to 2021 – Total 4339

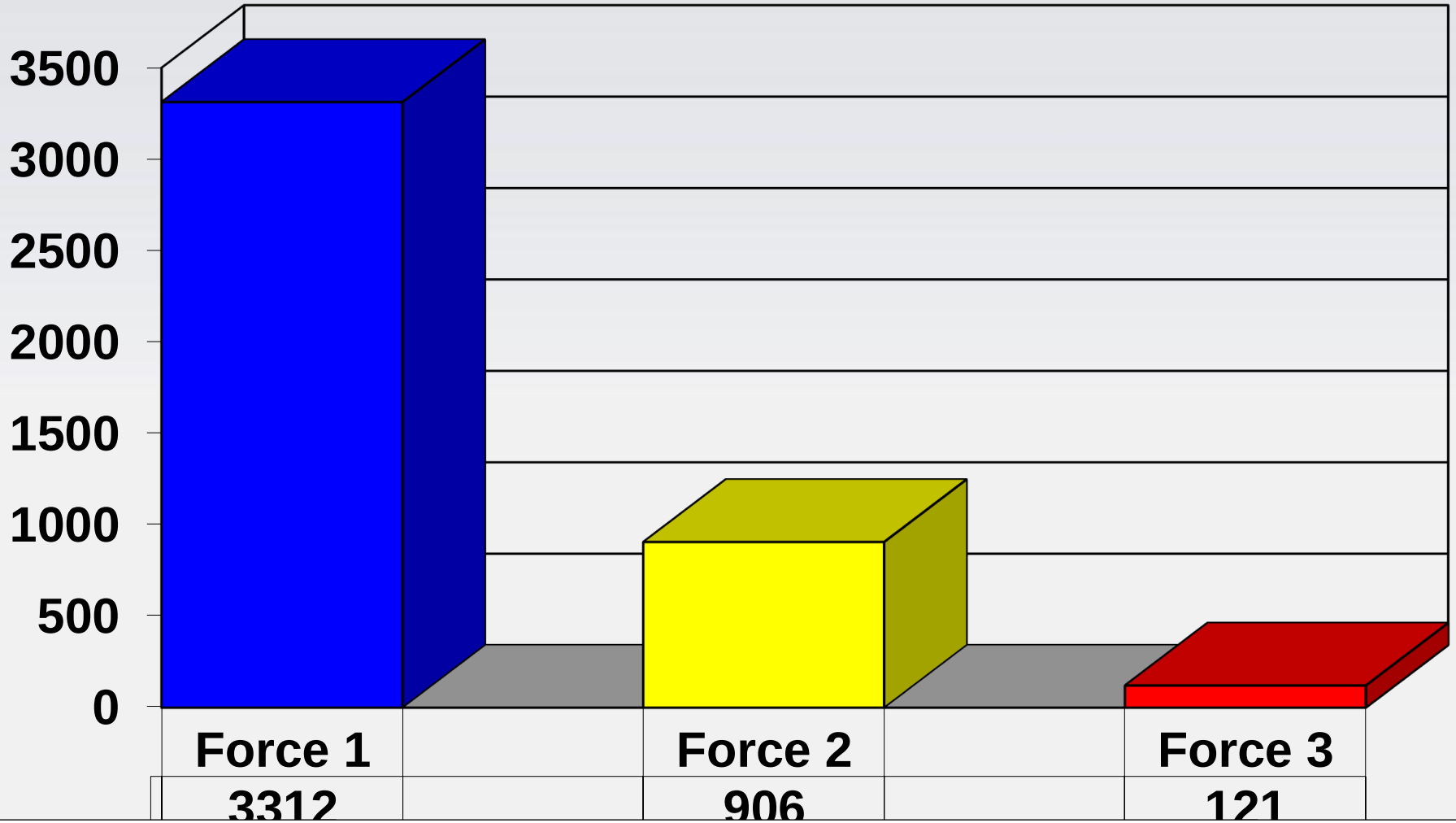


FIGURE 5. INCIDENTS BY FORCE LEVEL 1981 – 2021 **Sep. 2022**

All Force Levels by Percentage 1981 - 2021

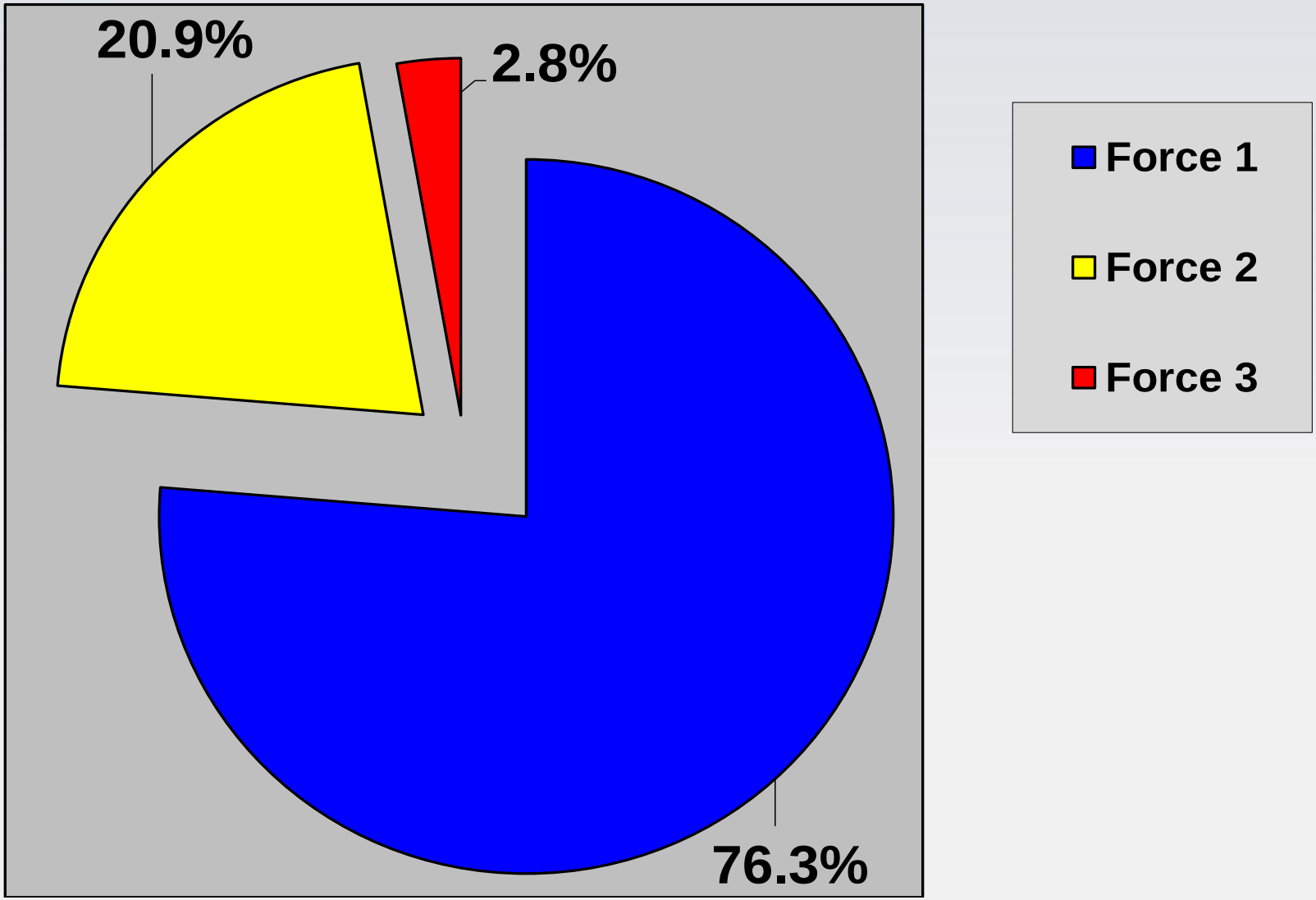


FIGURE 6. ALL FORCE LEVELS BY PERCENTAGE 1981 – 2021 **Sep. 2022**

Injuries from Incidents
1981 to 2021 (Total 1615 Injuries)

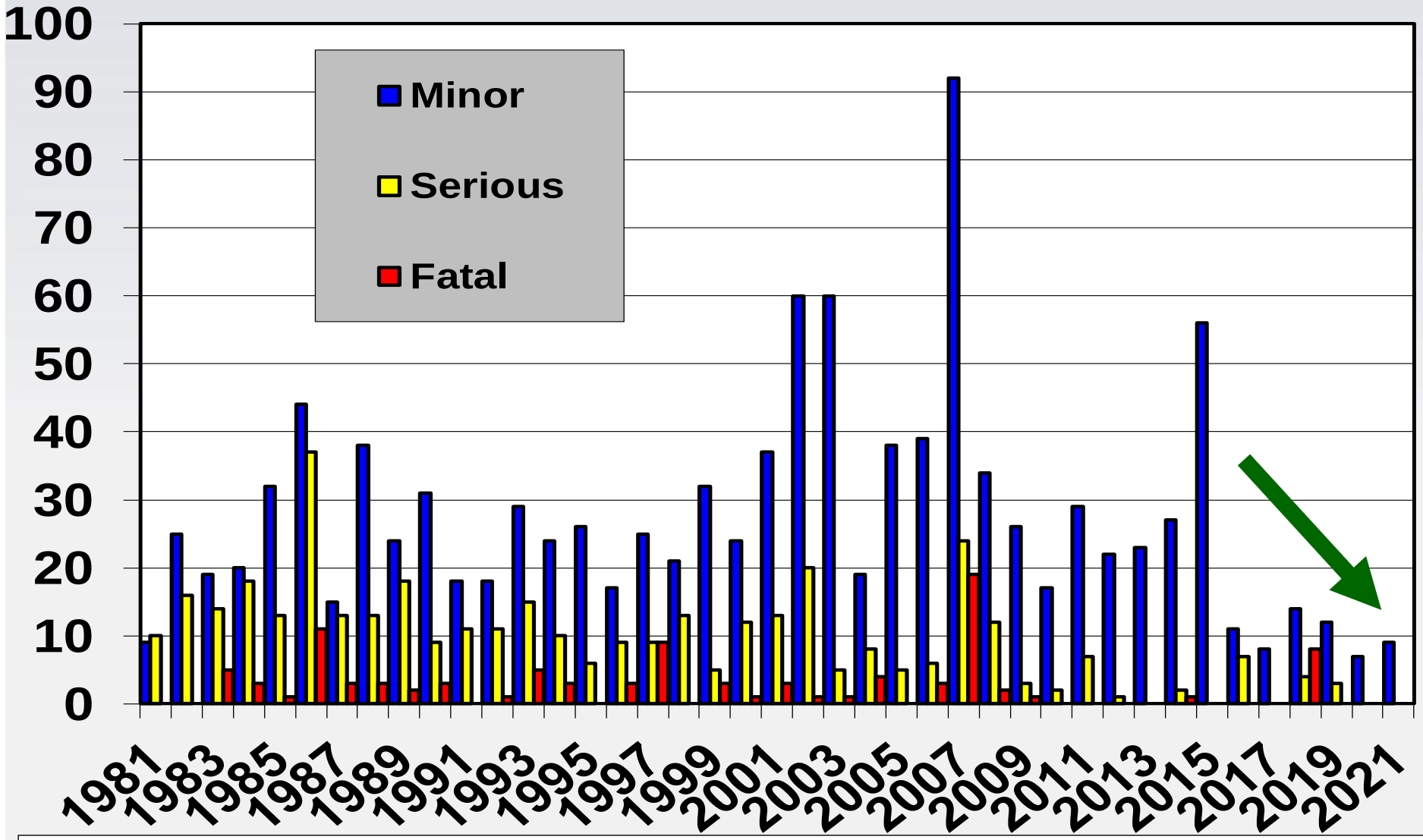


FIGURE 7. INJURIES FROM INCIDENTS FOR 1981 – 2021 Sep. 2022

Average # of Injuries / Year from Explosions 2001-2015 & 2016-2021

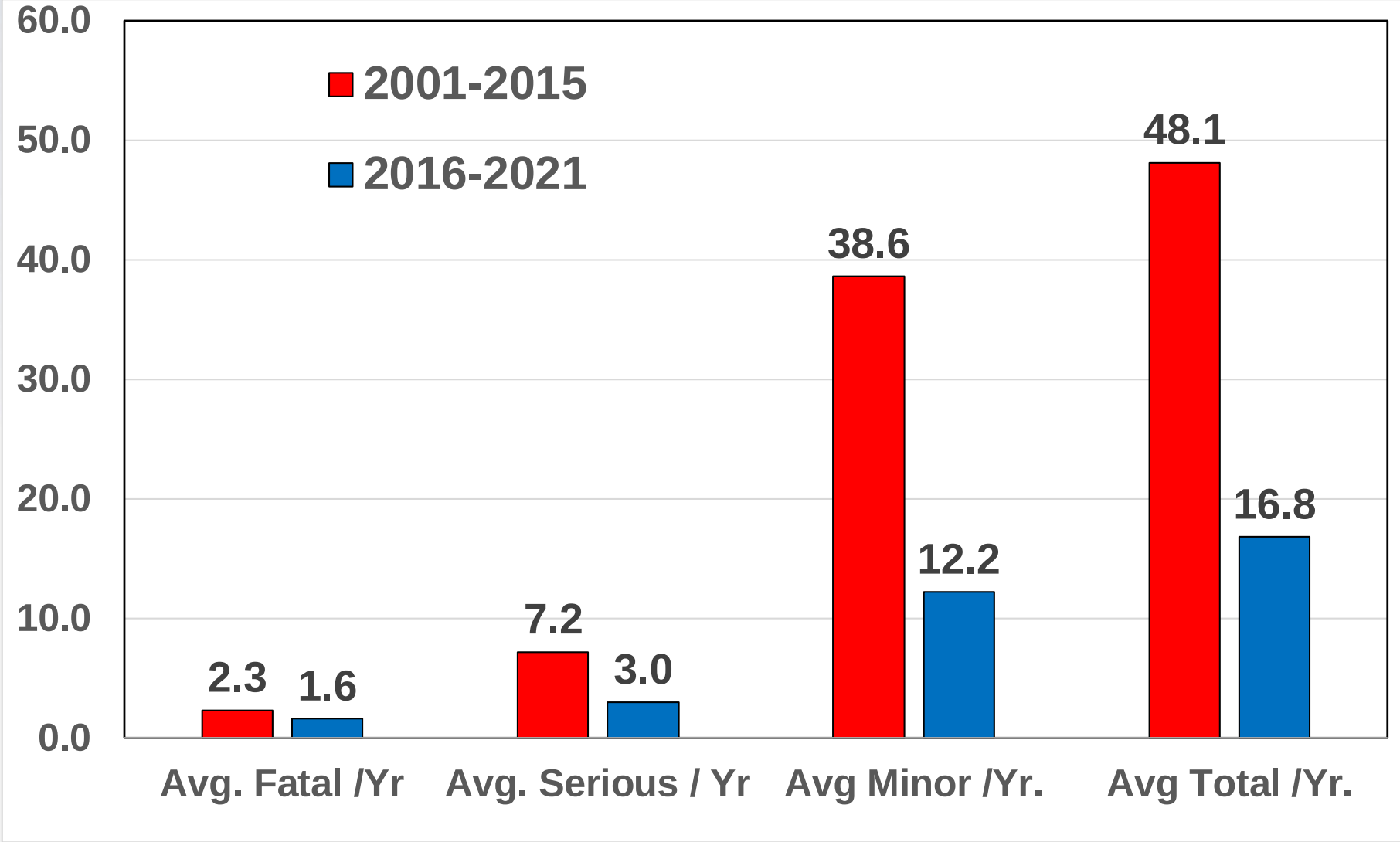


FIGURE 8. AVG. # INJURIES / YR. FOR 2001-2015 & 2016-2021 **Sep. 2022**

Injuries by Severity – Total 1615
1981 to 2021

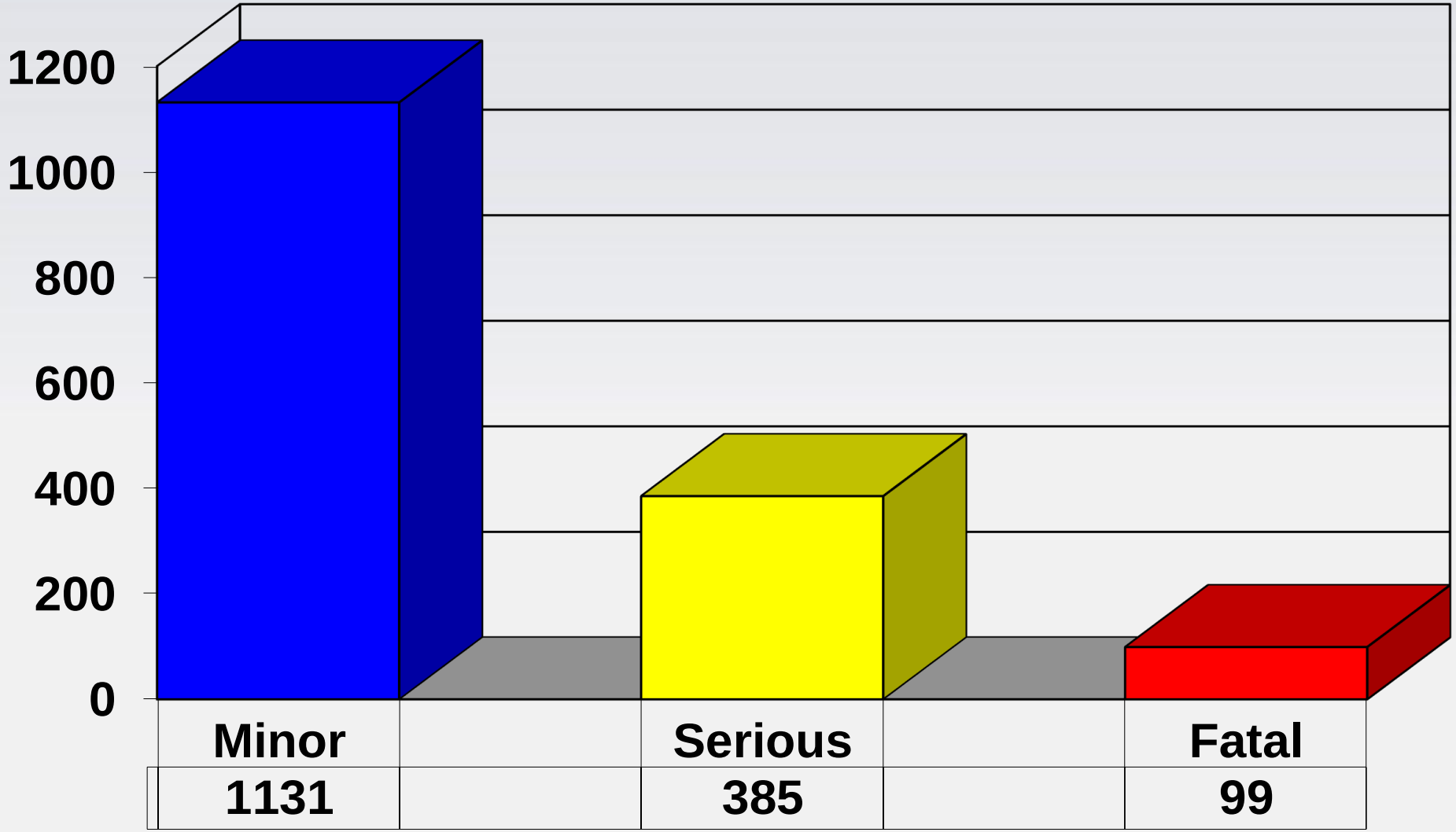


FIGURE 9. INJURIES BY SEVERITY FOR 1981 – 2021 **Sep. 2022**

Injury Levels by Percentage 1981 - 2021

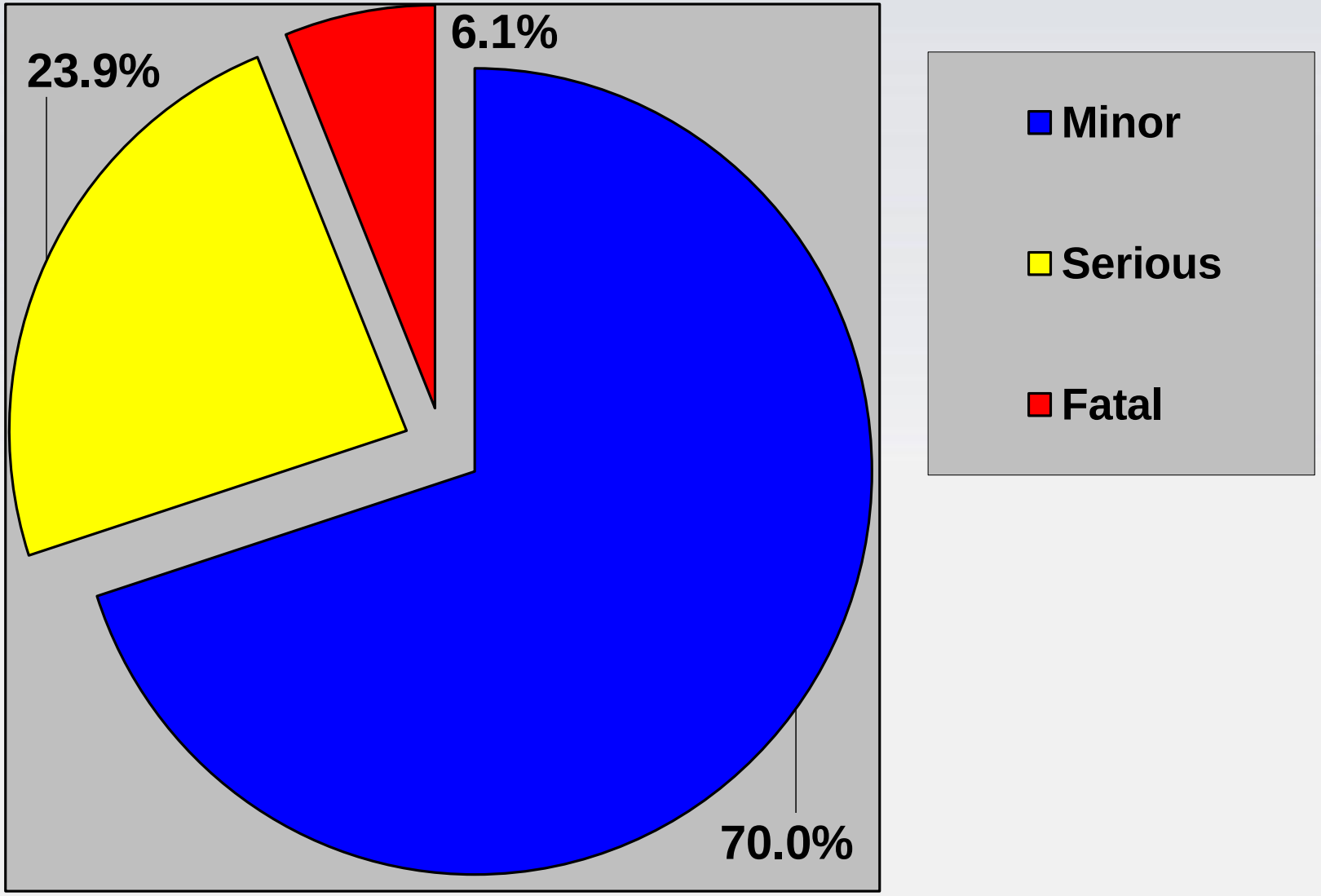
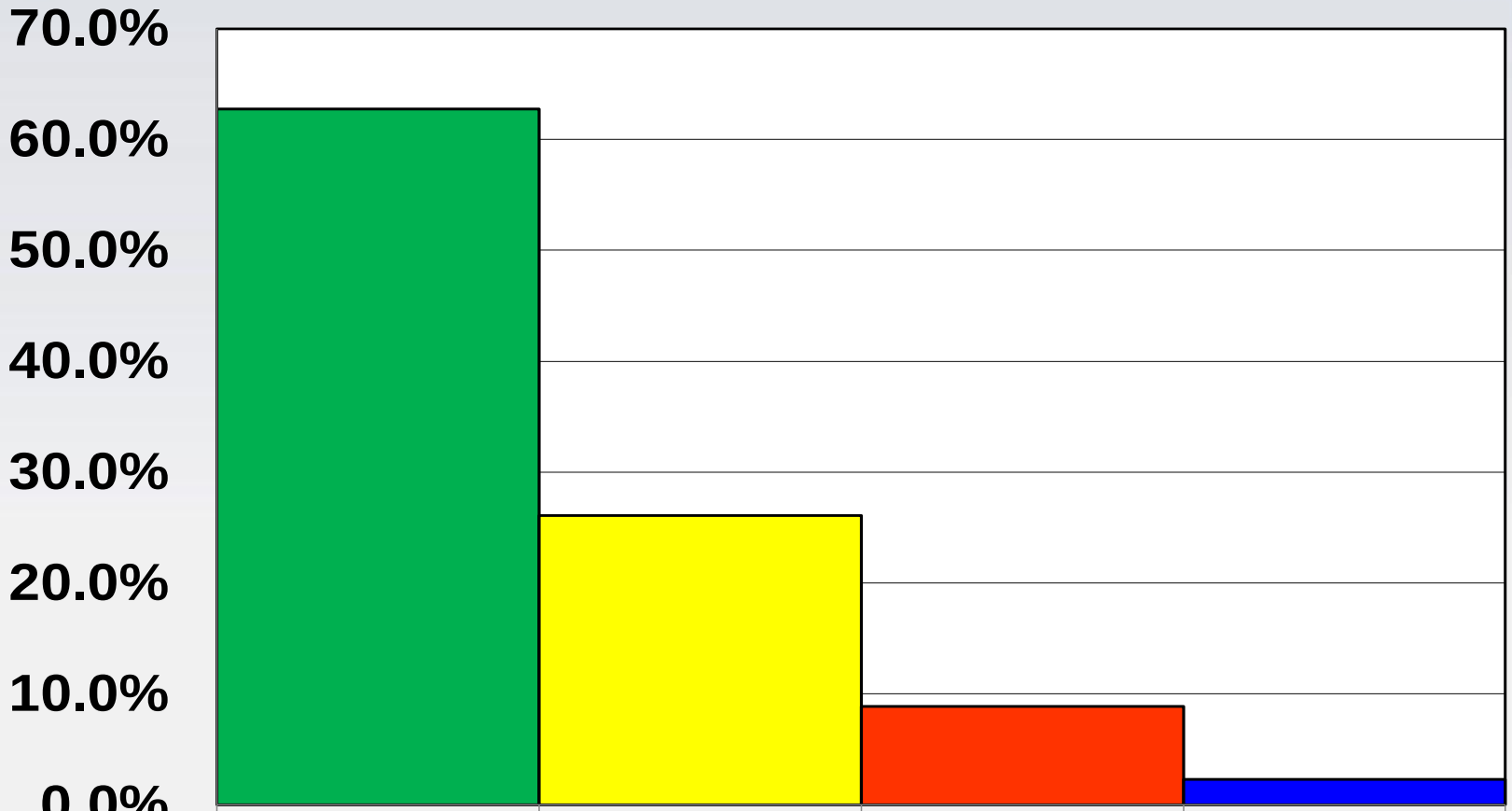


FIGURE 10. INJURY LEVELS BY PERCENTAGE FOR 1981 – 2021 **Sep. 2022**

Injury Risk per 100 Explosions 1980 - 2021



	No Injury	Minor	Serious	Fatal
%Injury / 100 Explosions	62.8%	26.1%	8.9%	2.3%

FIGURE 11. INJURY RISK PER 100 EXPLOSIONS FOR 1981 – 2021 Sep. 2022

Fatalities from Explosions 1981 to 2021

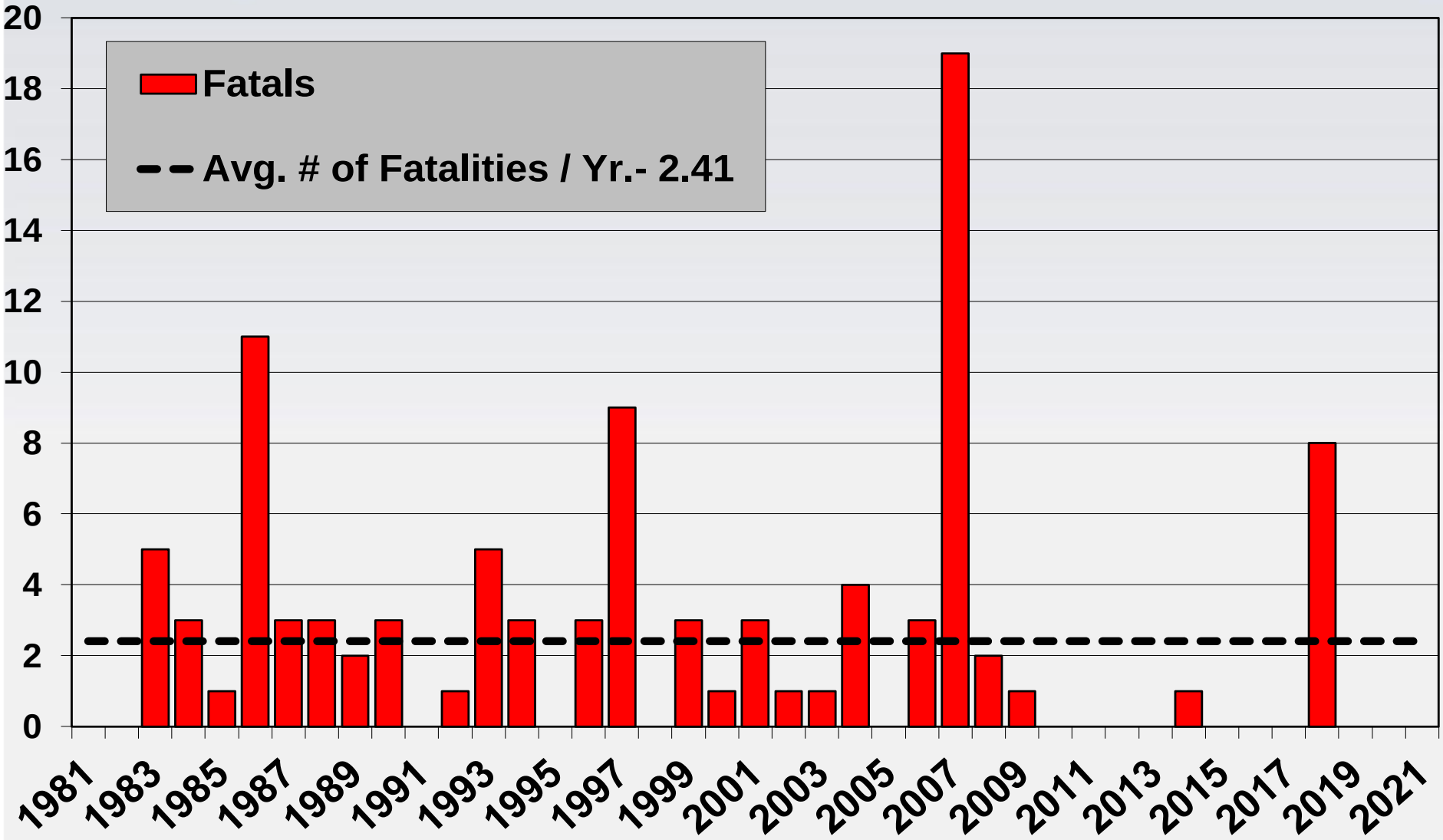
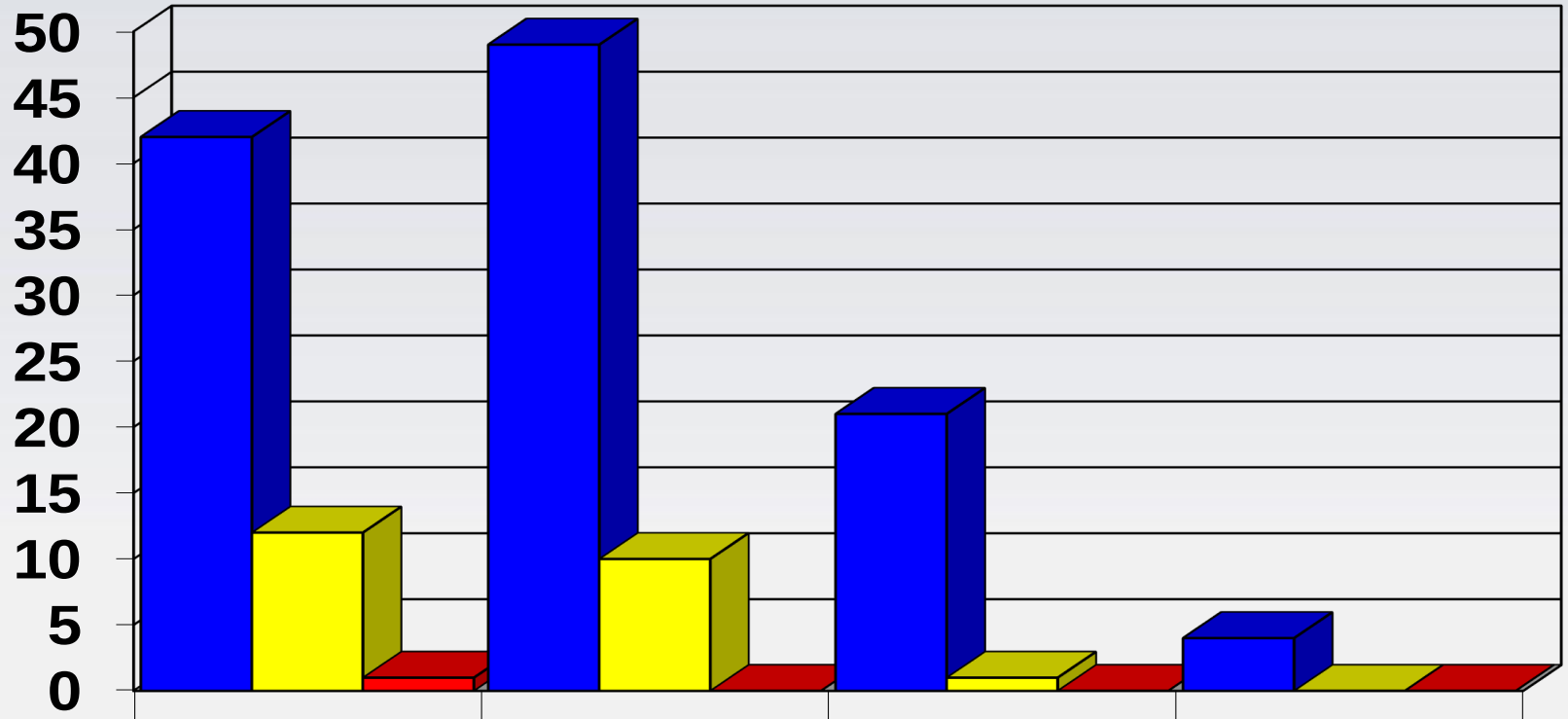


FIGURE 12. FATALITIES FROM EXPLOSIONS FOR 1981 – 2021 **Sep. 2022**

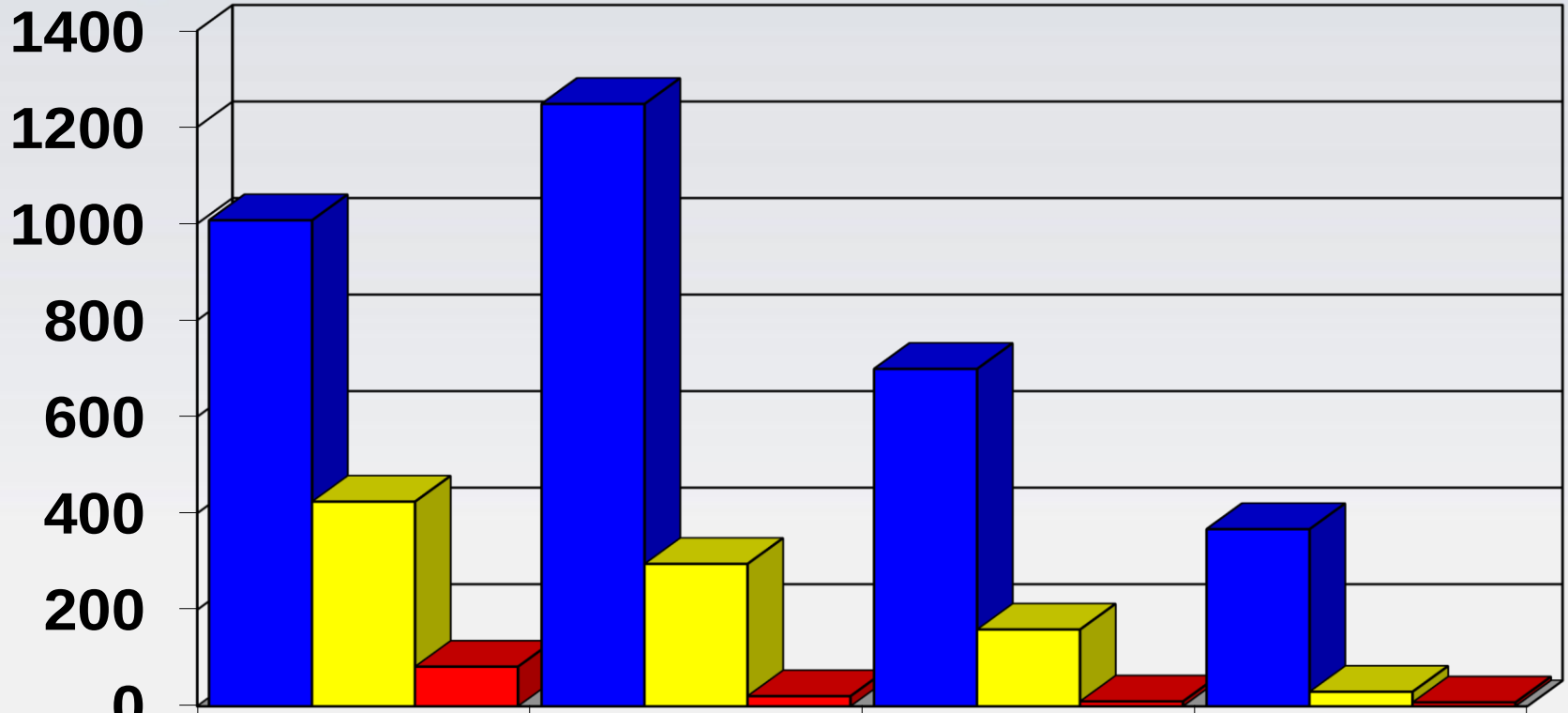
Force Level Incidents by Operation – 2021



	Melting	Casting	Transfer	Other
Force 1	42	49	21	4
Force 2	12	10	1	0
Force 3	1	0	0	0

FIGURE 13. FORCE LEVEL INCIDENTS BY OPERATION FOR 2021 Sep. 2022

Force Level Explosions by Operation 1980 to 2021



	Melting	Casting	Transfer	Other
Force 1	1007	1248	699	367
Force 2	424	295	159	30
Force 3	82	21	10	8

FIGURE 14. FORCE LEVEL EXPLOSIONS BY OPERATION 1980 – 2021 Sep. 2022

Melting Injuries and Incidents 1990 to 2021 (Total 334 Injuries)

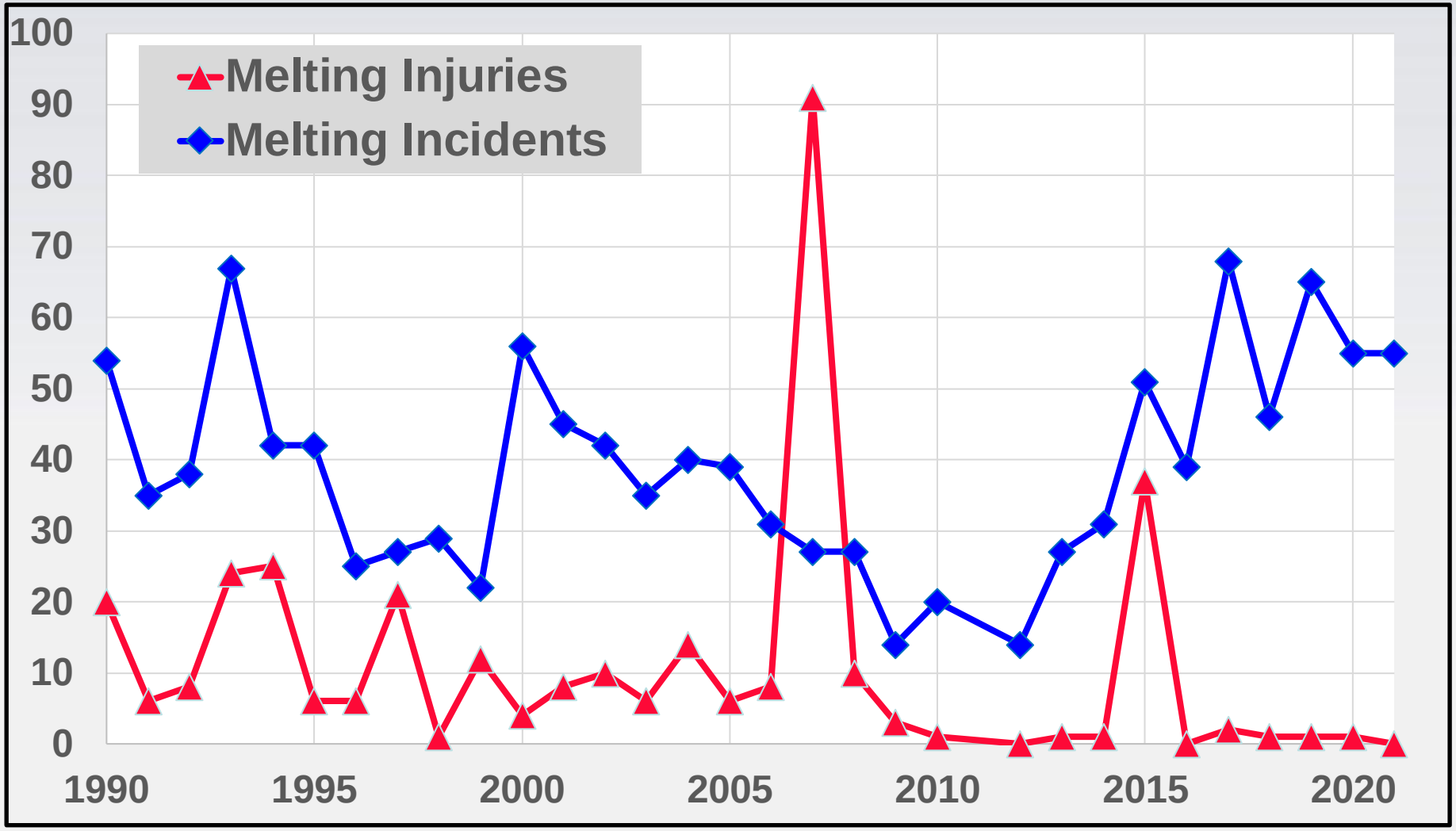


FIGURE 15. MELTING INJURIES AND INCIDENTS FOR 1990 – 2021 Sep. 2022

Melting Injuries per Incidents 1990 to 2021

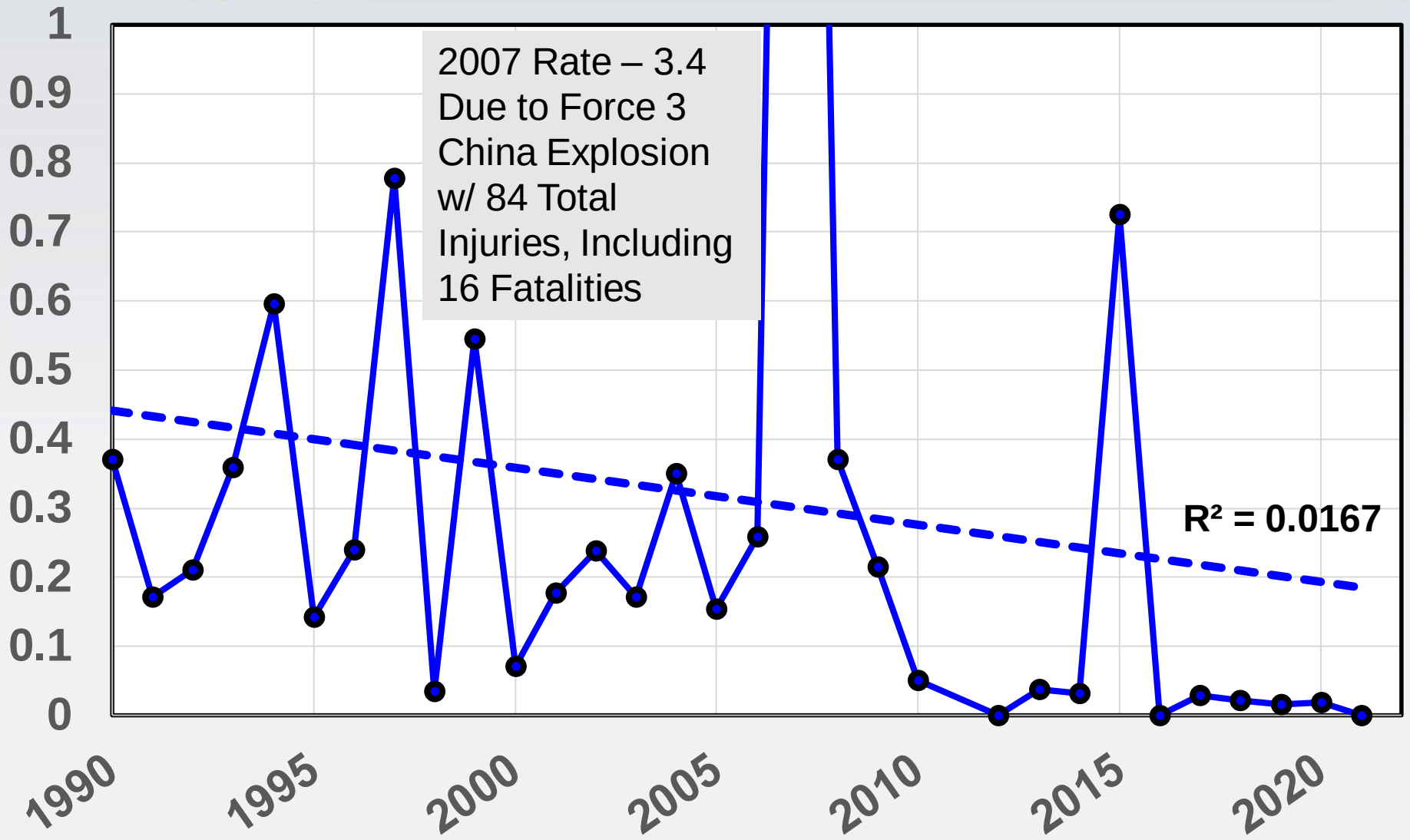


FIGURE 16. MELTING INJURIES PER INCIDENTS FOR 1990 – 2021 Sep. 2022

Casting Injuries and Incidents 1990 to 2021 (Total 356 Injuries)

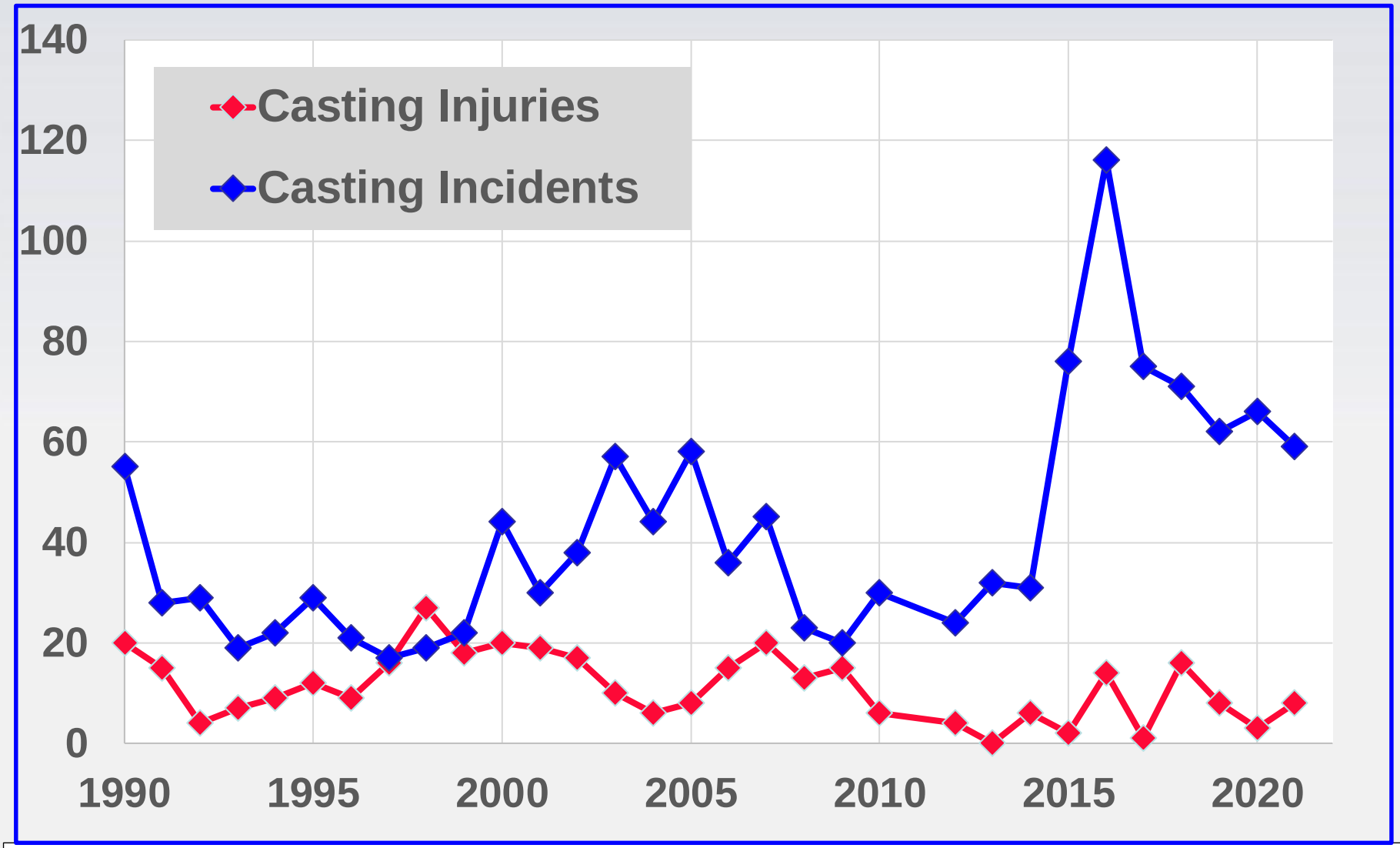


FIGURE 17. CASTING INJURIES AND INCIDENTS FOR 1990 – 2021 Sep. 2022

Casting Injuries per Incidents 1990 to 2021

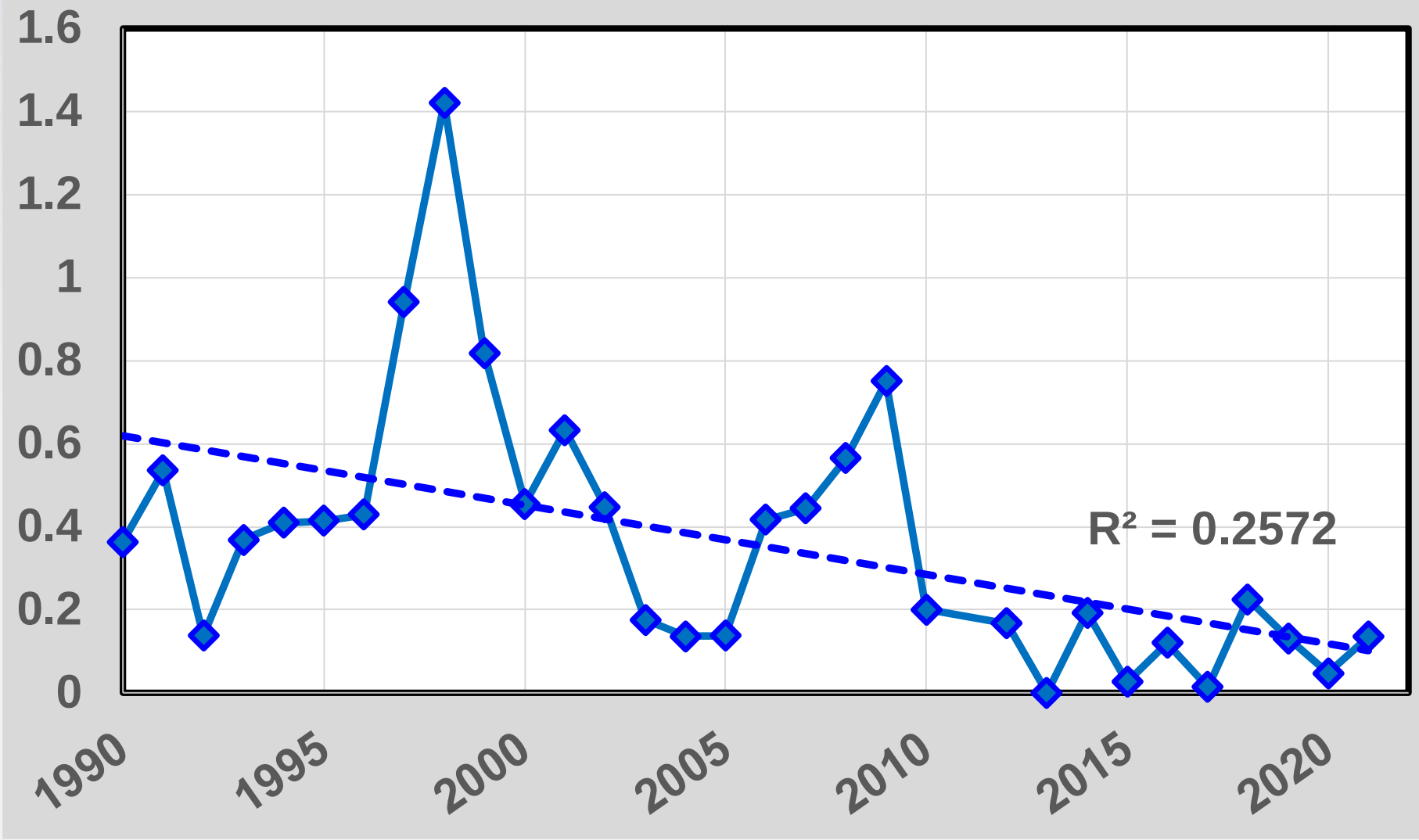


FIGURE 18. CASTING INJURIES PER INCIDENTS FOR 1990 – 2022 Sep. 2022

Transfer Injuries and Incidents 1990 to 2021 (Total 342 Injuries)

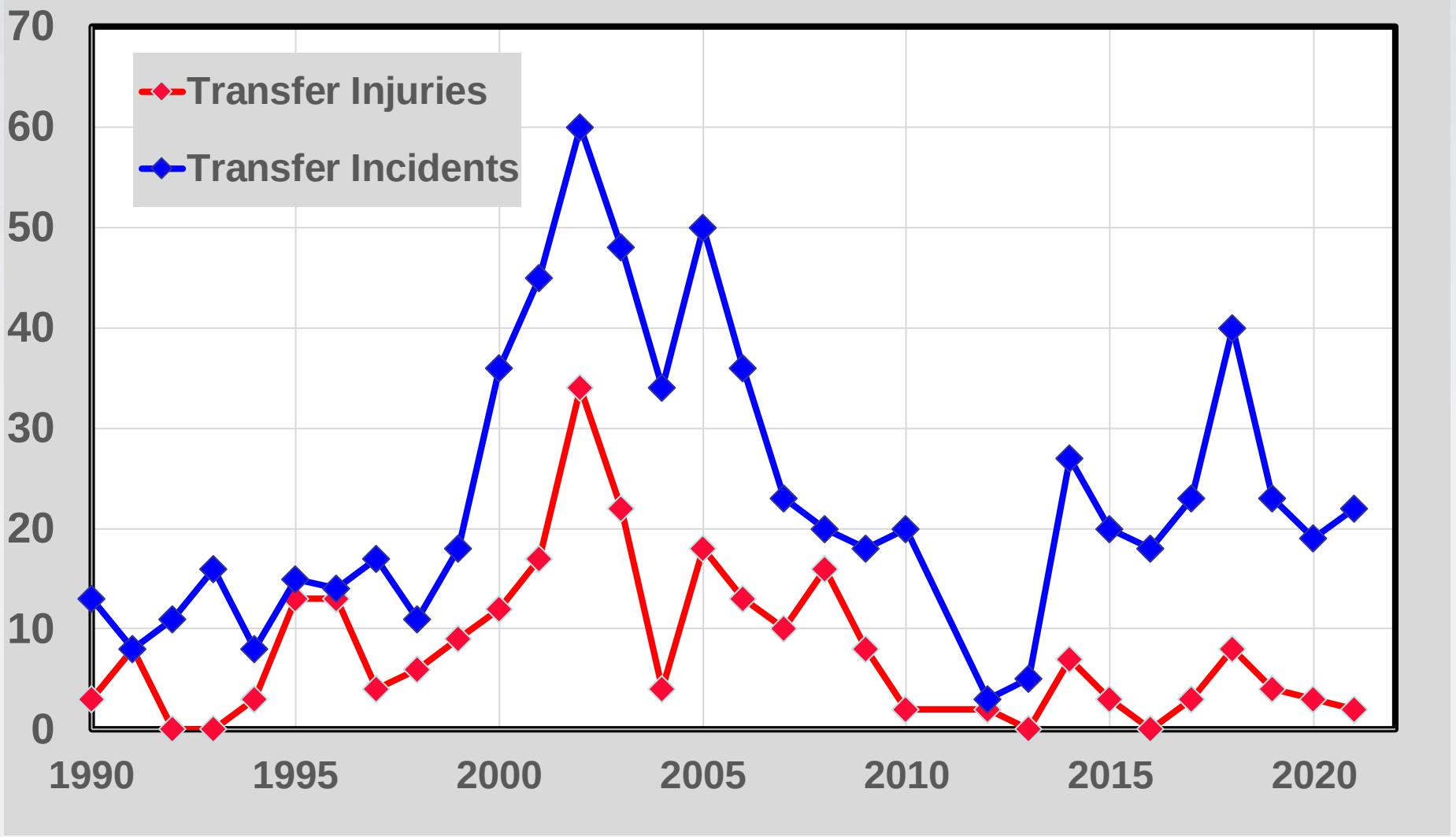


FIGURE 19. CASTING INJURIES AND INCIDENTS FOR 1990 – 2021 Sep. 2022

Transfer Injuries per Incidents 1990 to 2021

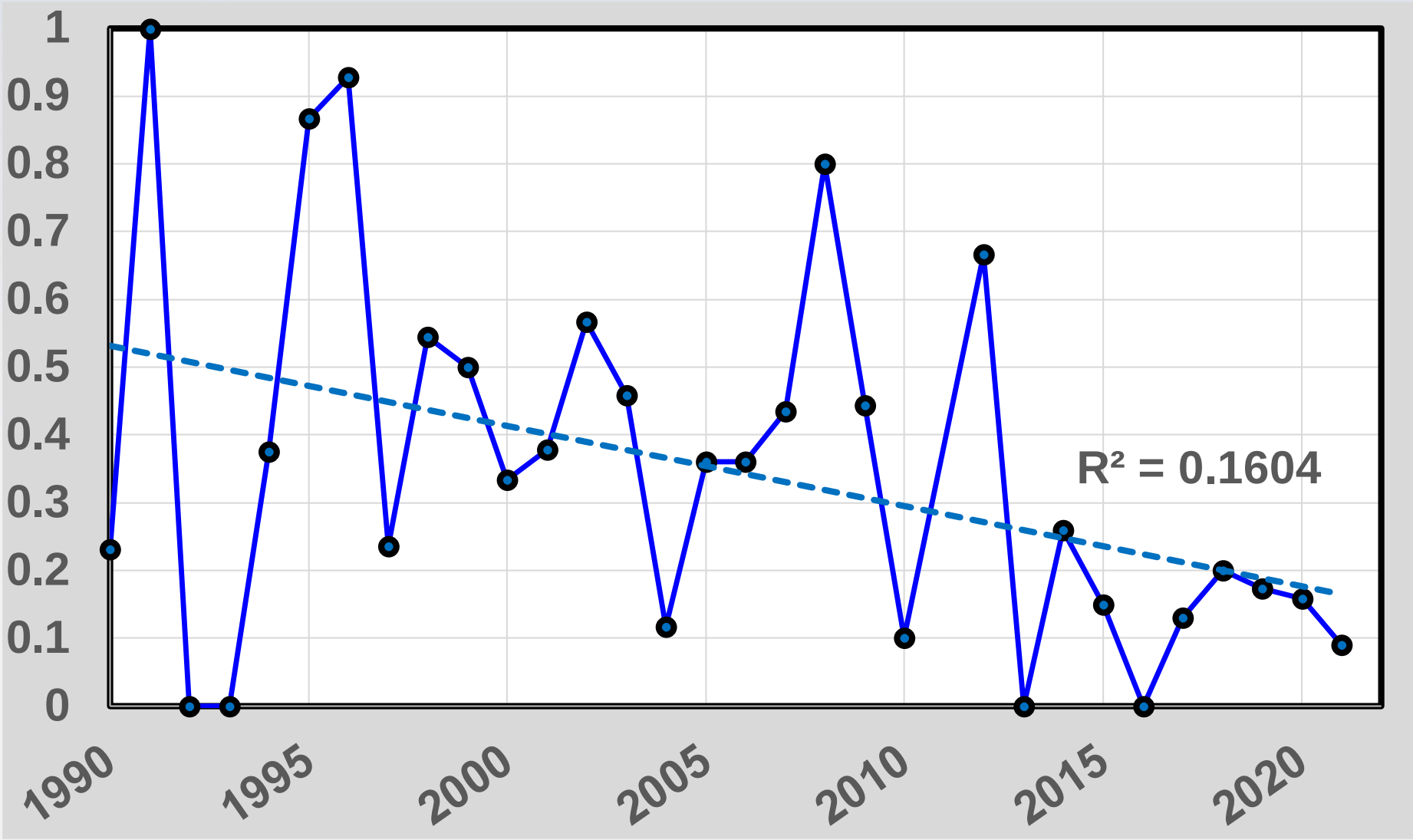
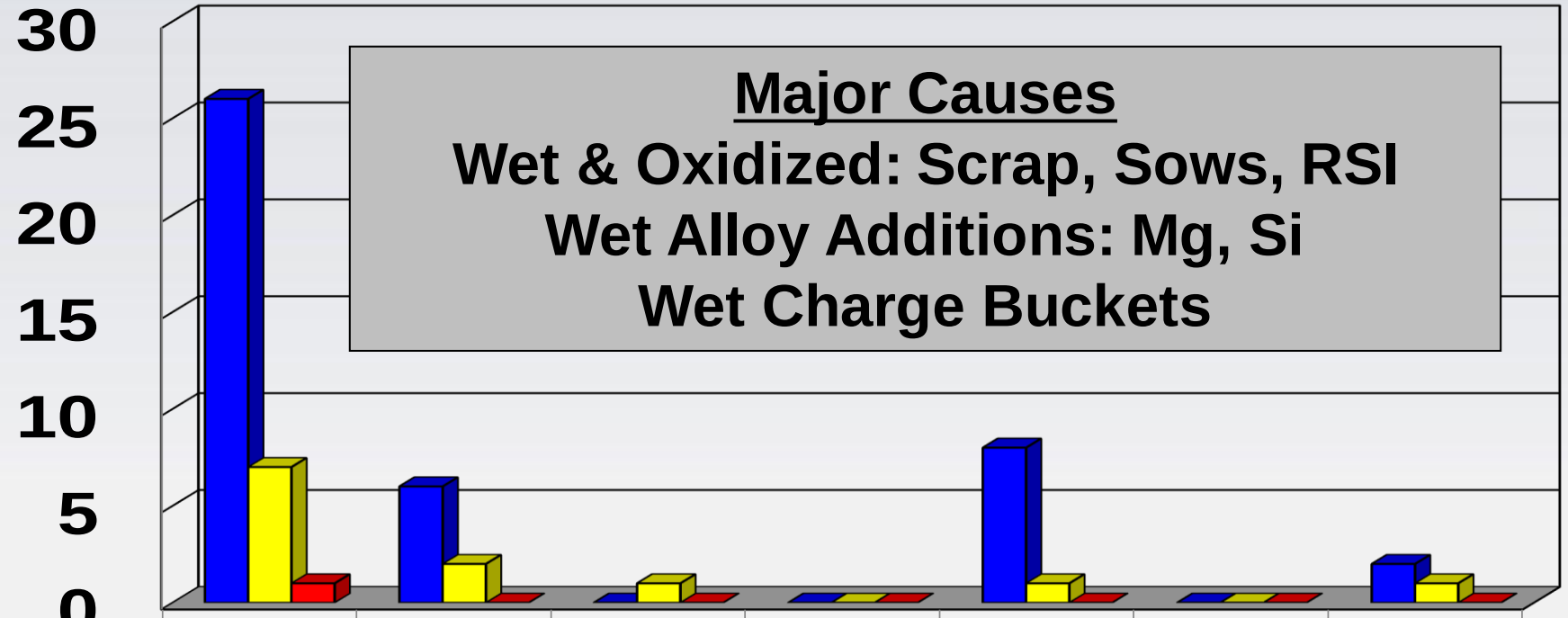


FIGURE 20. TRANSFER INJURIES PER INCIDENTS FOR 1990–2021 Sep. 2022

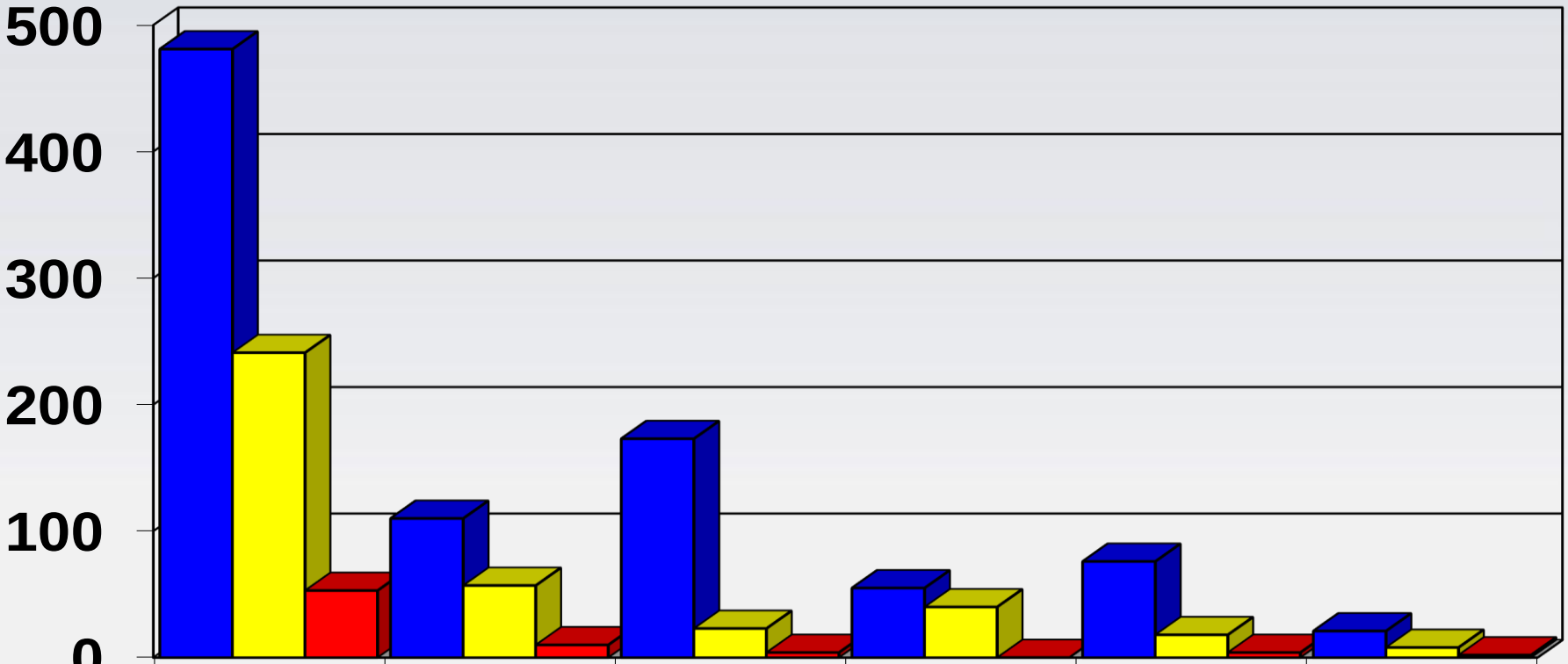
55 Melting Explosions - 2021



	Scrap Charge	Sow Charge	RSI Charge	T-Bar	Alloy-ing Mg / Other	Tools / Pans	Other
Force 1	26	6	0	0	8	0	2
Force 2	7	2	1	0	1	0	1
Force 3	1	0	0	0	0	0	0

FIGURE 21. MELTING EXPLOSIONS BY CAUSE FOR 2021 Sep. 2022

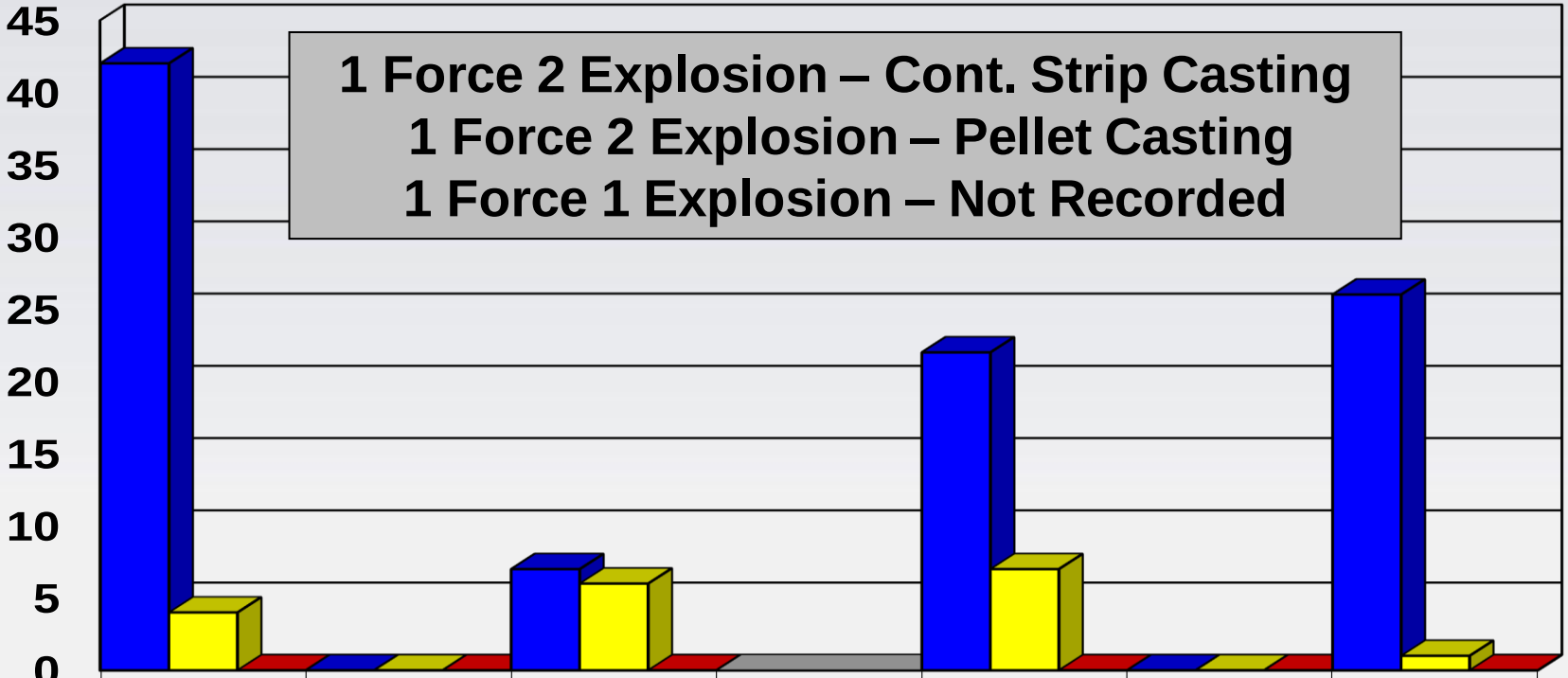
Melting Explosions - Charge Material Involved 1980 - 2021



	Scrap	Sow	Alloy Adds	Ingot / Tbar	Other	Scrap / Sow
Force 1	481	110	173	55	76	21
Force 2	241	57	23	40	18	8
Force 3	53	10	4	0	4	2

FIGURE 22. MELTING EXPLOSIONS BY CHARGE MATERIAL 1980 – 2021 Sep. 2022

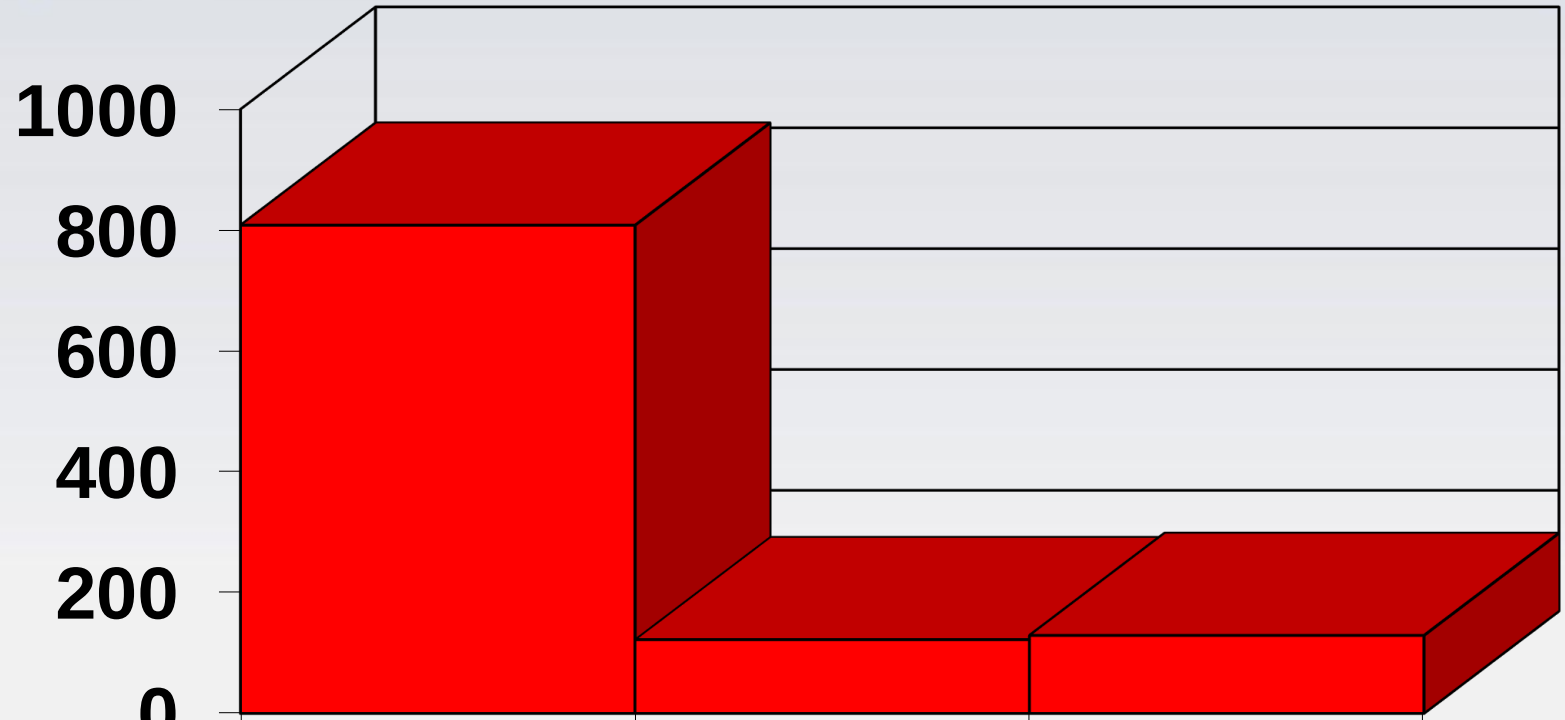
59 Casting Explosions - 2021



	Start-up	Steady State	Termina - tion		DC Slab & Billet	Rod	Sow or Mold
Force 1	42	0	7		22	0	26
Force 2	4	0	6		7	0	1
Force 3	0	0	0		0	0	0

FIGURE 23. CASTING EXPLOSIONS FOR 2021 Sep. 2022

DC/HDC/EMC Explosions by Cast Segment 1980 to 2021



	Start-up	Steady State	End of Cast
# of Explosions	808	122	129

FIGURE 24. CASTING EXPLOSIONS by CAST SEGMENT 1981 – 2021 Sep. 2022

1. Major Causes of 60 Casting Incidents – 2021

- **DC Start-up Issues: Wet Starting Blocks, Wet Equipment / Launder, Butt Curl – Bleed-overs, Equipment Set-up, Ingot Hang-up & Release**
- **DC Steady State Issues: No Steady State Explosions!**
- **DC Termination Issues: Wet Rusty Drain Pan, Wet Tool, Trough Overflow**
- **Sow / Mold Casting Issues: Wet / Cracked Molds, Wet Equipment / Tools**

FIGURE 25. MAJOR CAUSES OF CASTING INCIDENTS FOR 2021 Sep. 2022

MAJOR CAUSES OF CASTING EXPLOSIONS
2015 thru 2021

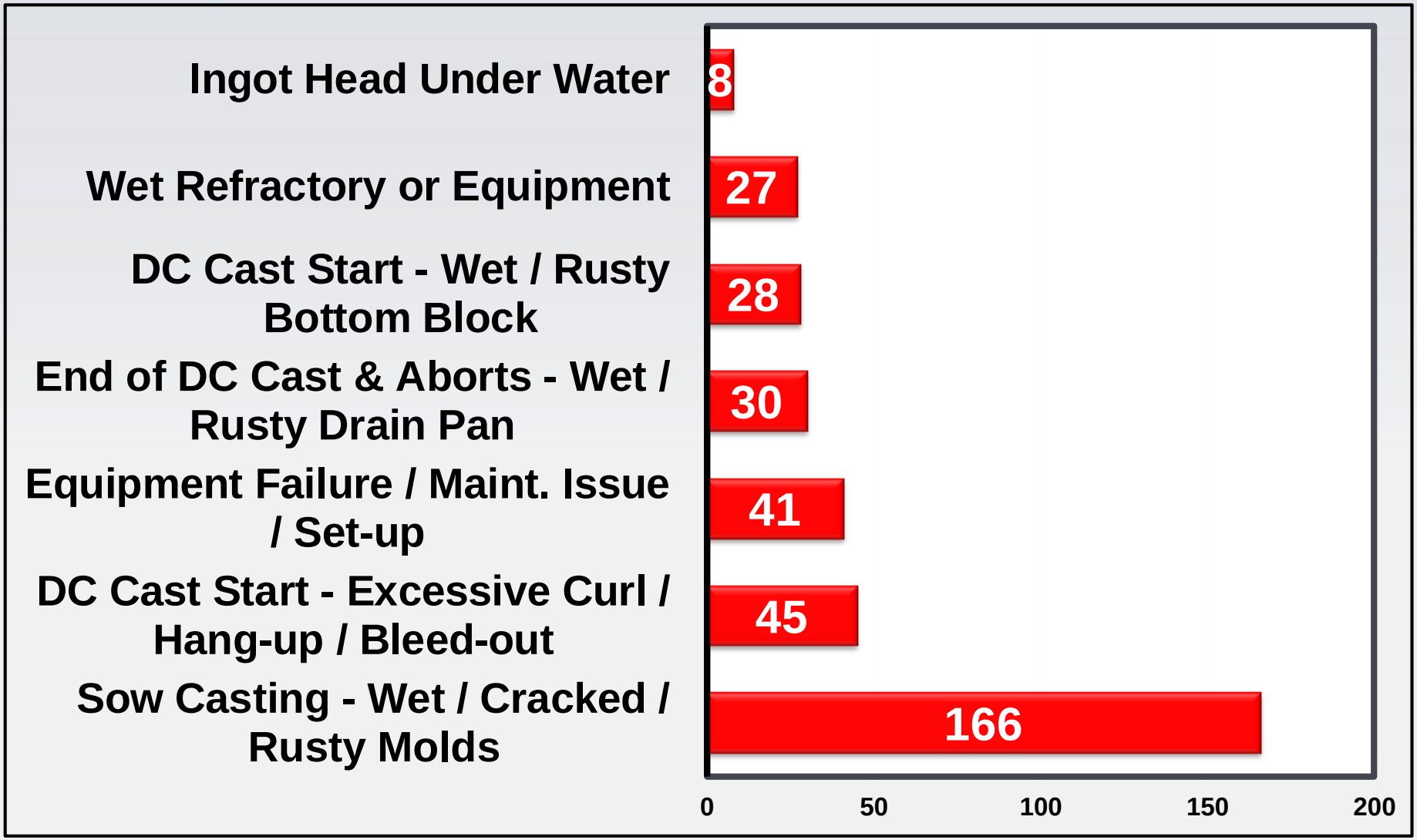


FIGURE 26. CASTING EXPLOSIONS by MAJOR CAUSES 2015–2021 Sep. 2022

MAJOR CAUSES OF FORCE 2 & 3 CASTING EXPLOSIONS - 2015 thru 2021

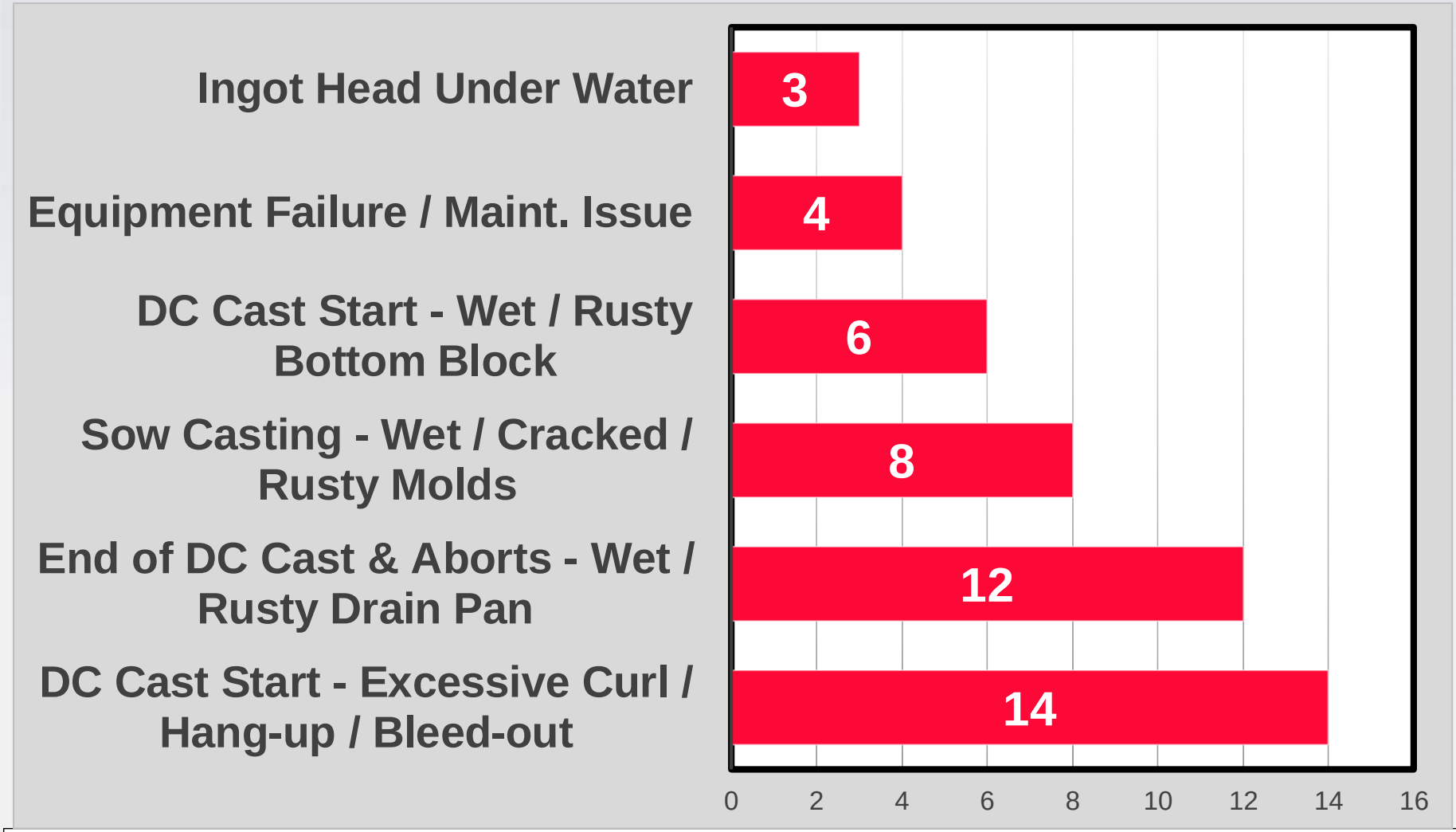


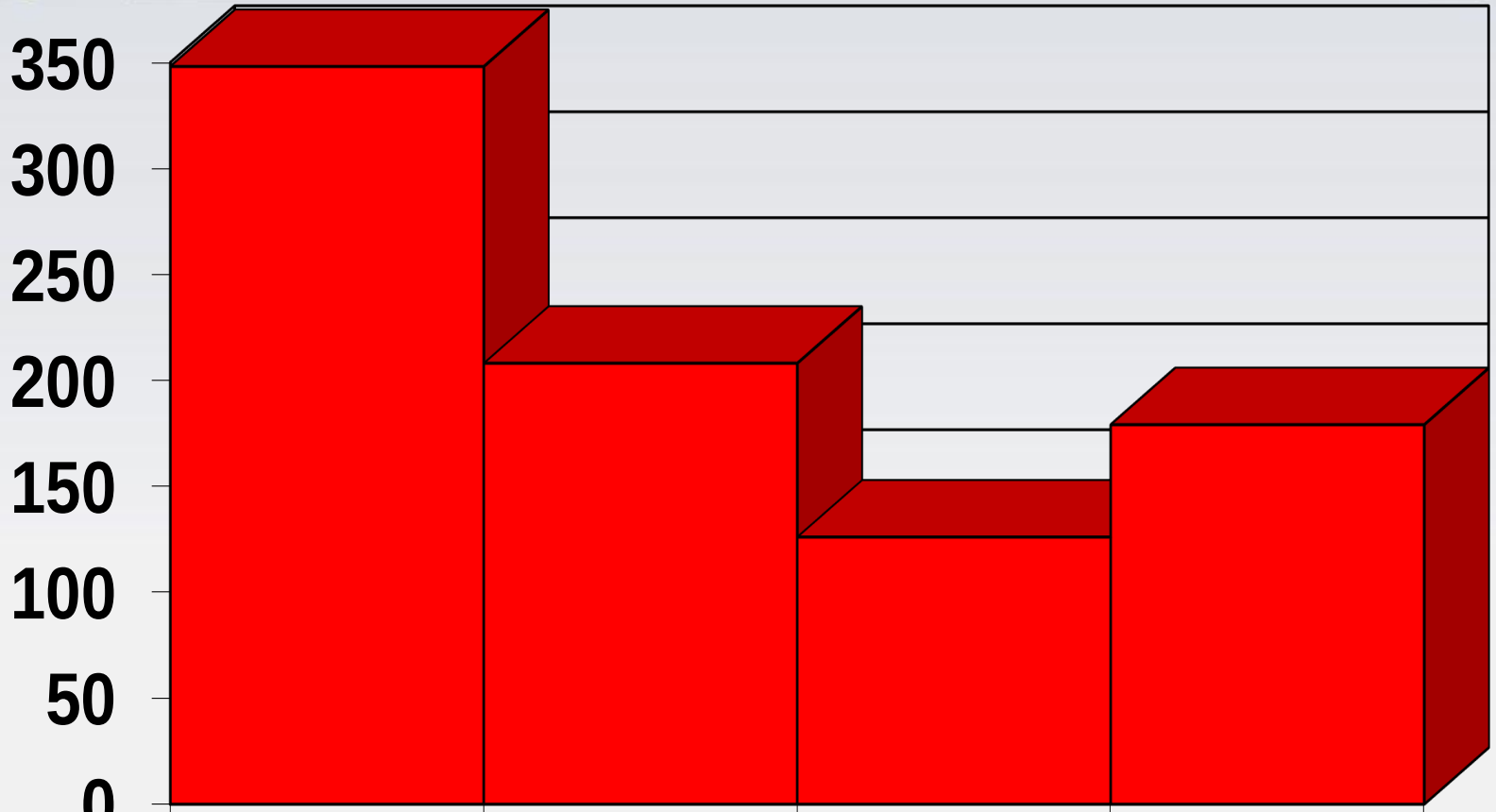
FIGURE 27. CASTING EXPLOSIONS by MAJOR CAUSES 2015–2021 Sep. 2022

Major Causes of 22 Transfer Explosions - 2021

13 - Wet Hand or Fce Tools, Equipment
6 - Wet / Rusty Drain or Skim Pan
2 – Equipment Falling into Trough / Launder
1 – Sow Not Solidified Dumped on Floor

FIGURE 28. CAUSES OF TRANSFER EXPLOSIONS FOR 2021 **Sep. 2022**

Transfer Explosions by Equipment – Total 862
1980 to 2021



	Drain Pan	Trough	Cruci-ble	Other
# of Explosions	348	208	126	179

FIGURE 29. TRANSFER EXPLOSIONS by EQUIPMENT 1980 – 2021 Sep. 2022

MAJOR CAUSES OF TRANSFER EXPLOSIONS
2008 thru 2021 (w/o 2011)

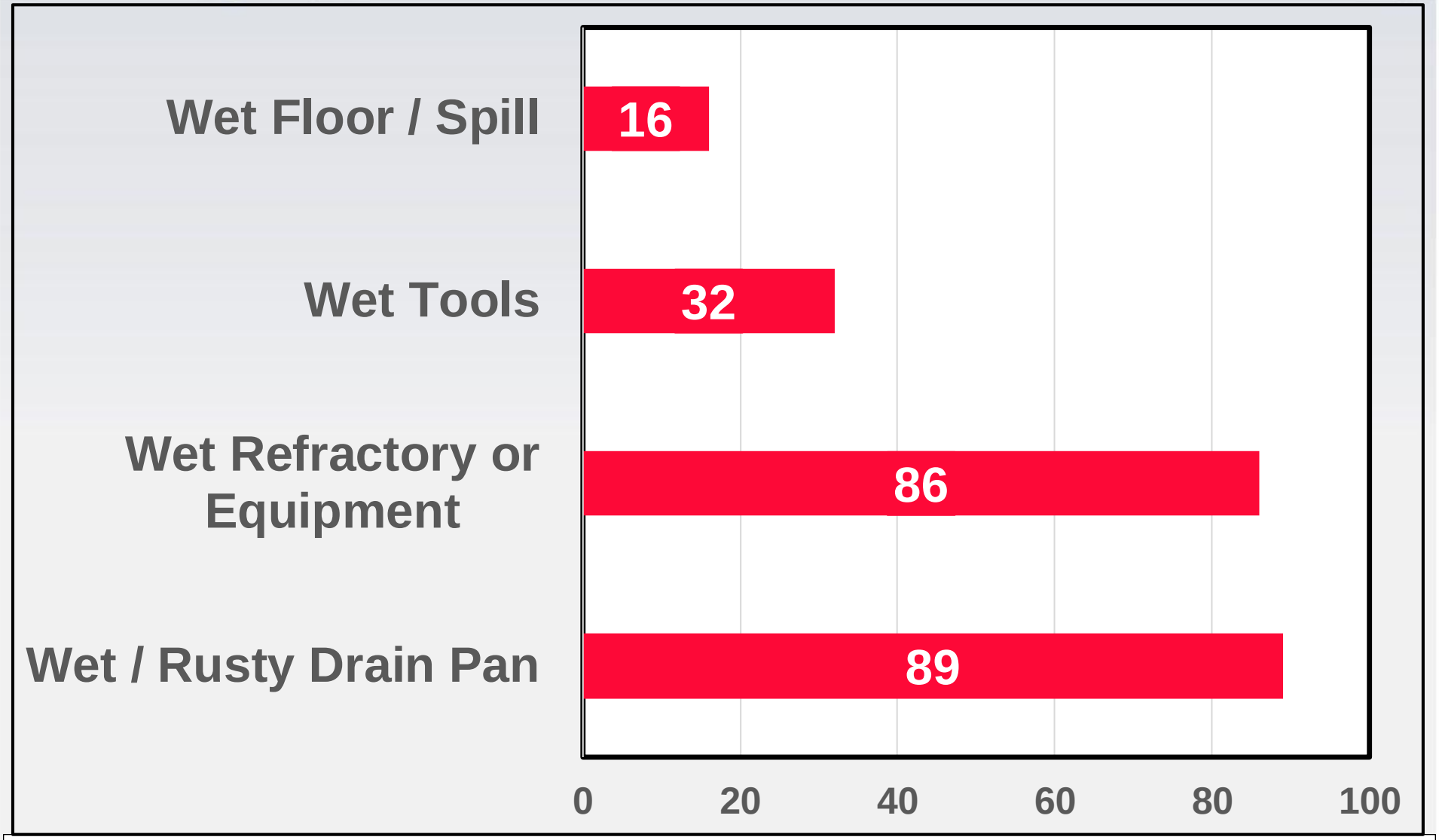


FIGURE 30. TRANSFER EXPLOSIONS - MAJOR CAUSES 2008–2021 Sep. 2022

MAJOR CAUSES OF FORCE 2 & 3 TRANSFER EXPLOSIONS - 2008 thru 2021 (w/o 2011)

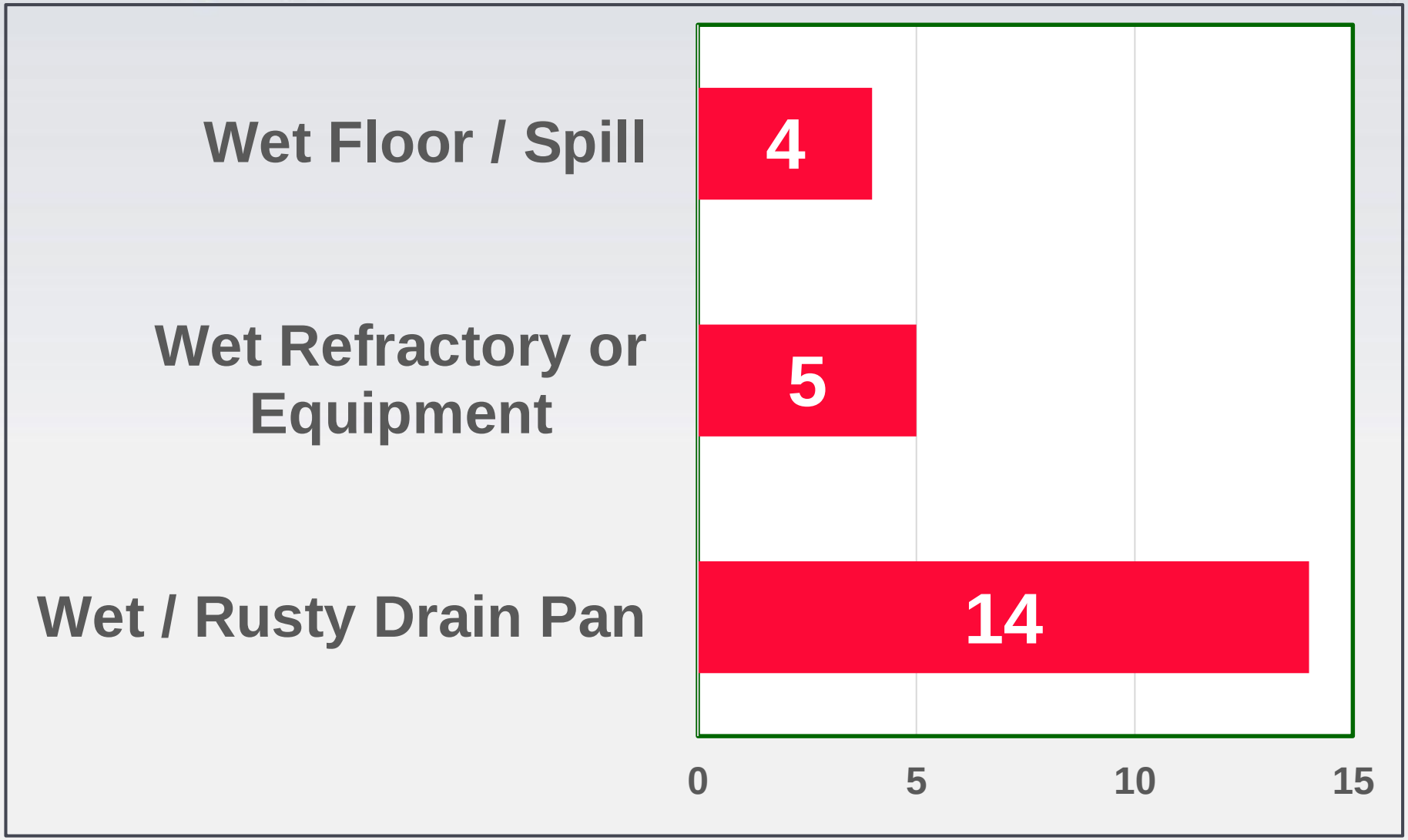
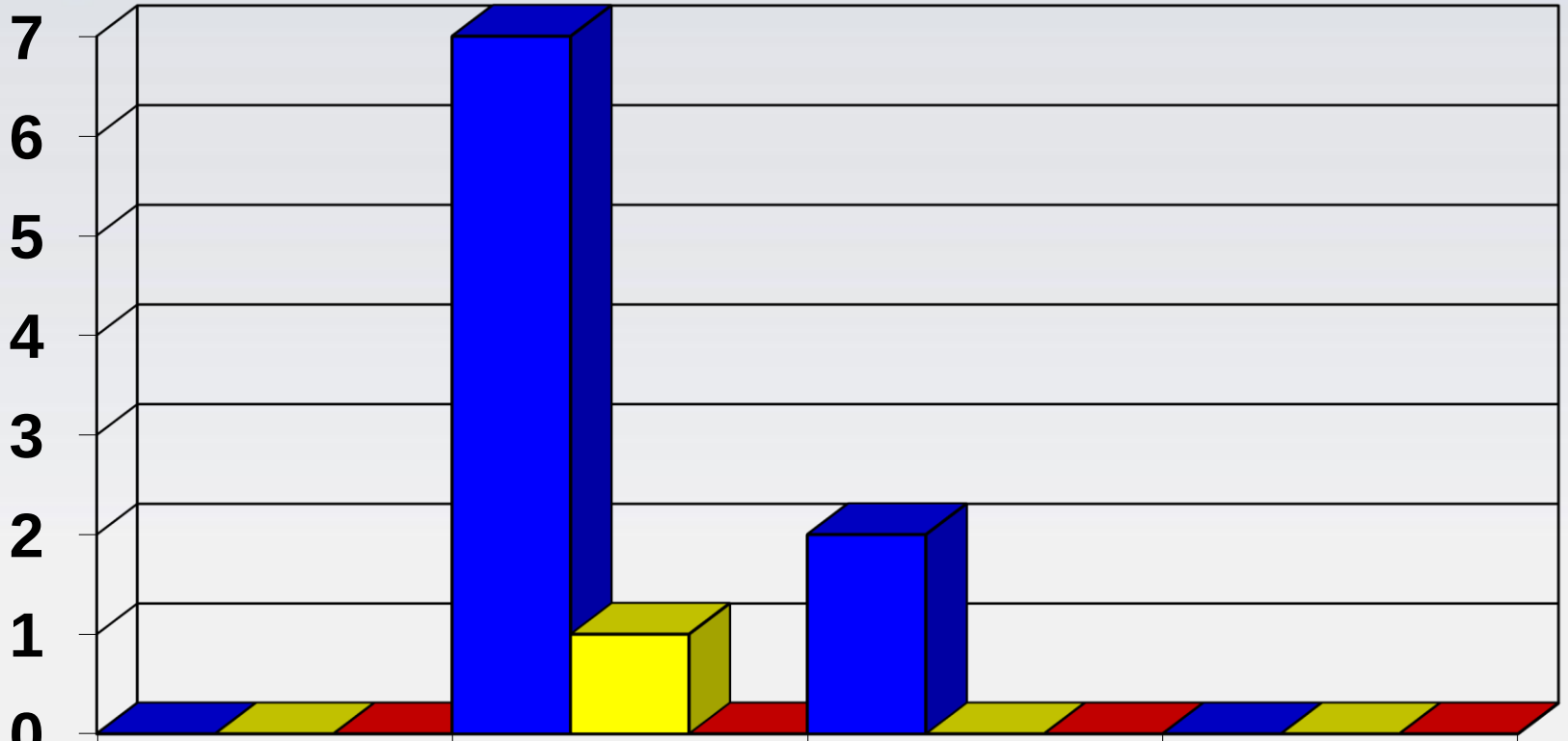


FIGURE 31. TRANSFER EXPLOSIONS - MAJOR CAUSES 2008–2021 Sep. 2022

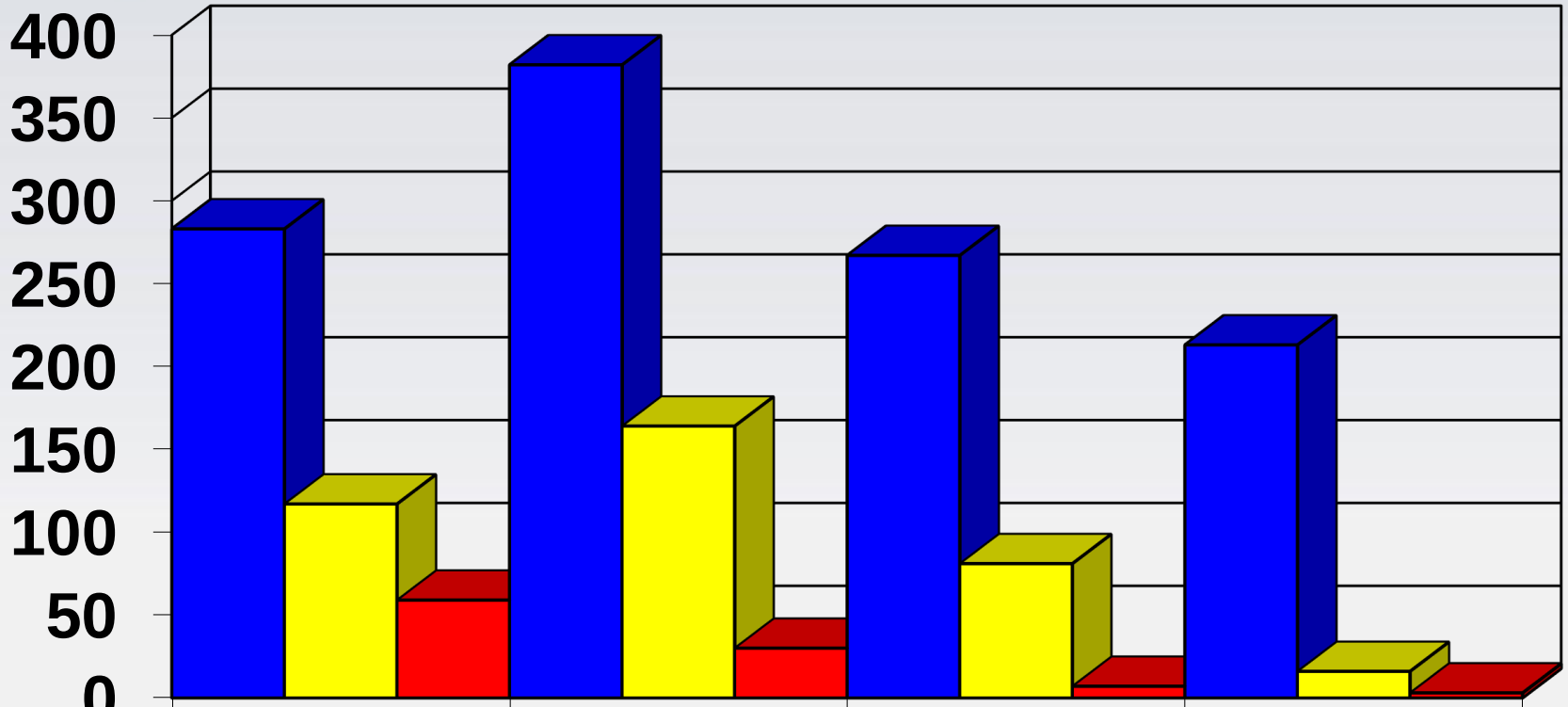
10 Injuries by Operation - 2021



	Melting	Casting	Transfer	Other
Minor	0	7	2	0
Serious	0	1	0	0
Fatal	0	0	0	0

FIGURE 32. INJURIES BY OPERATION FOR 2021 Sep. 2022

1612 Injuries by Operation: 1981 – 2021



	Melting	Casting	Transfer	Other
Minor	283	382	267	213
Serious	117	164	81	16
Fatal	59	30	7	3

FIGURE 33. INJURIES BY OPERATION FOR 1980 - 2021 Sep. 2022

Melting Explosions by Month 2017 to 2021

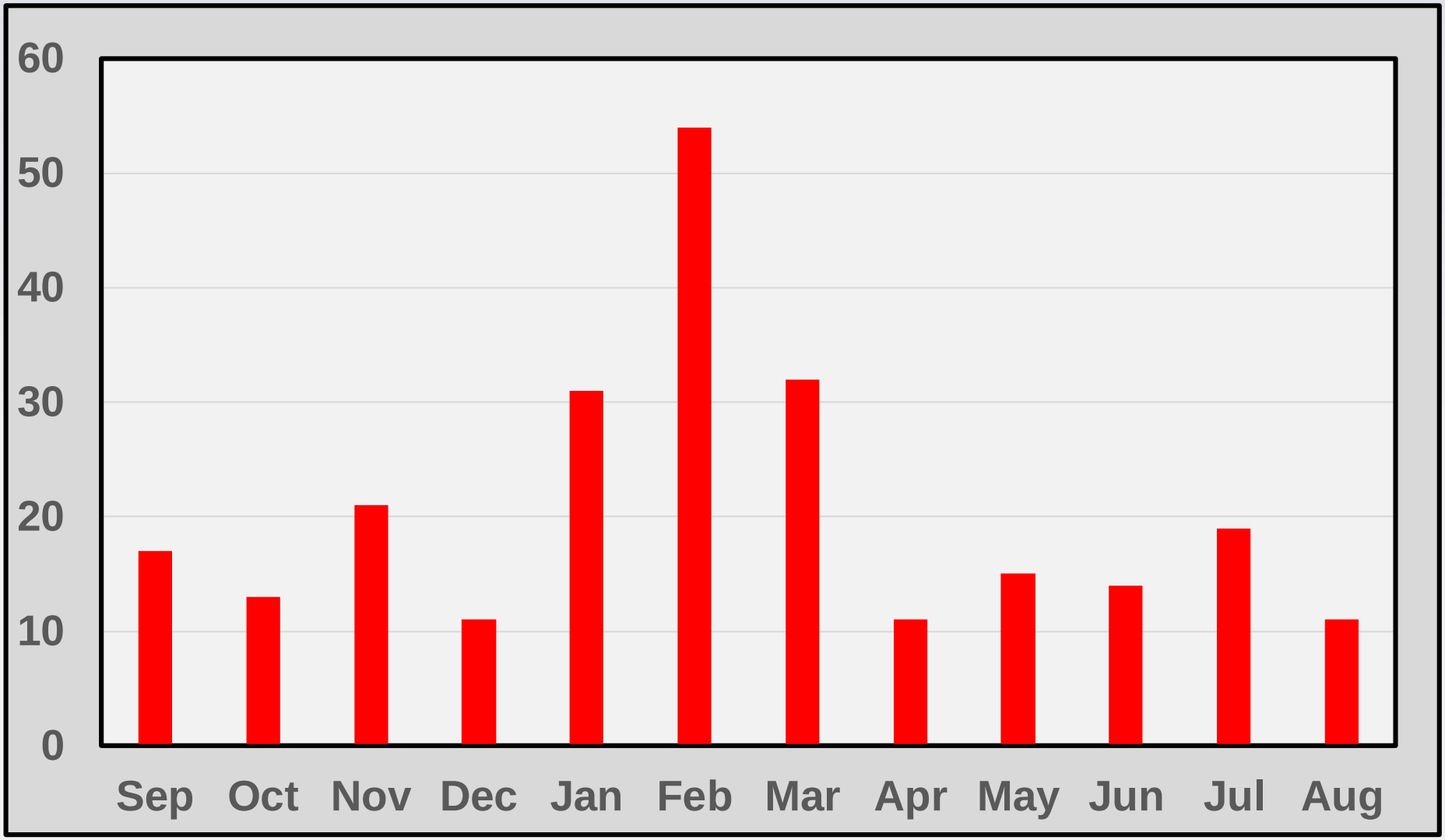


FIGURE 34. Melting EXPLOSIONS by Month 2017 – 2021 **Sep. 2022**

Casting Explosions by Month 2017 to 2021

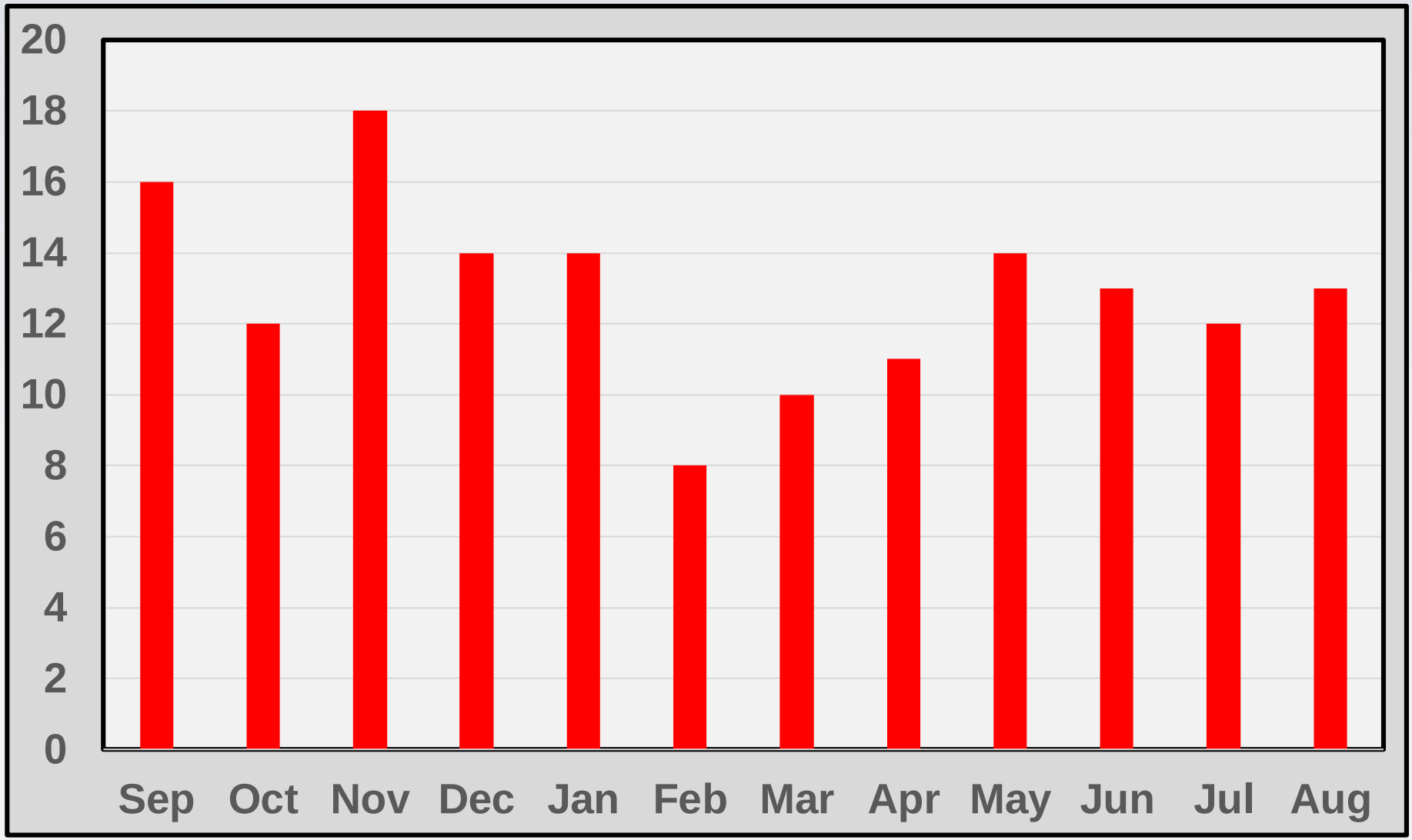


FIGURE 35. Casting EXPLOSIONS by Month 2017 – 2021 **Sep. 2022**

Casting Explosions by Month 2017 to 2021

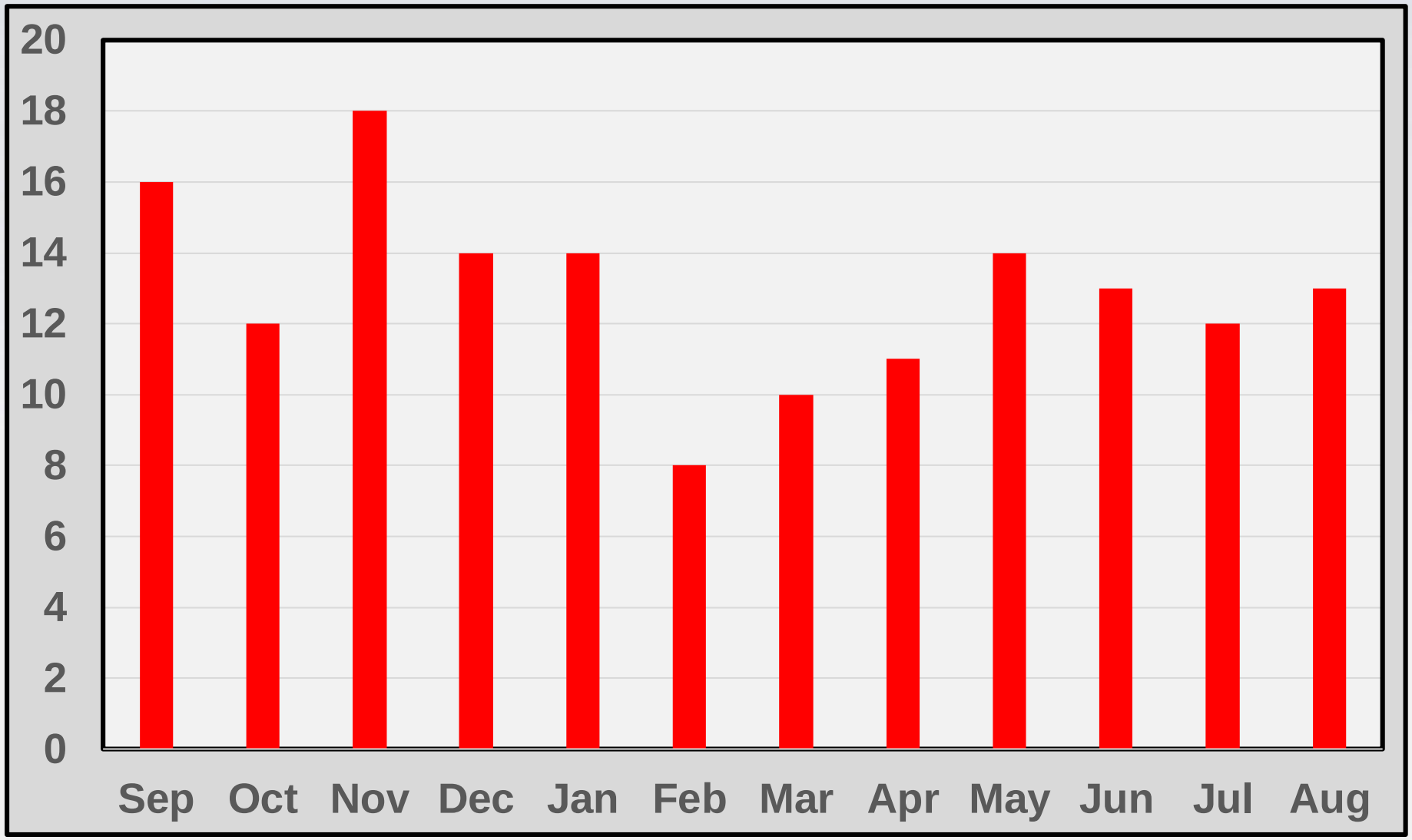
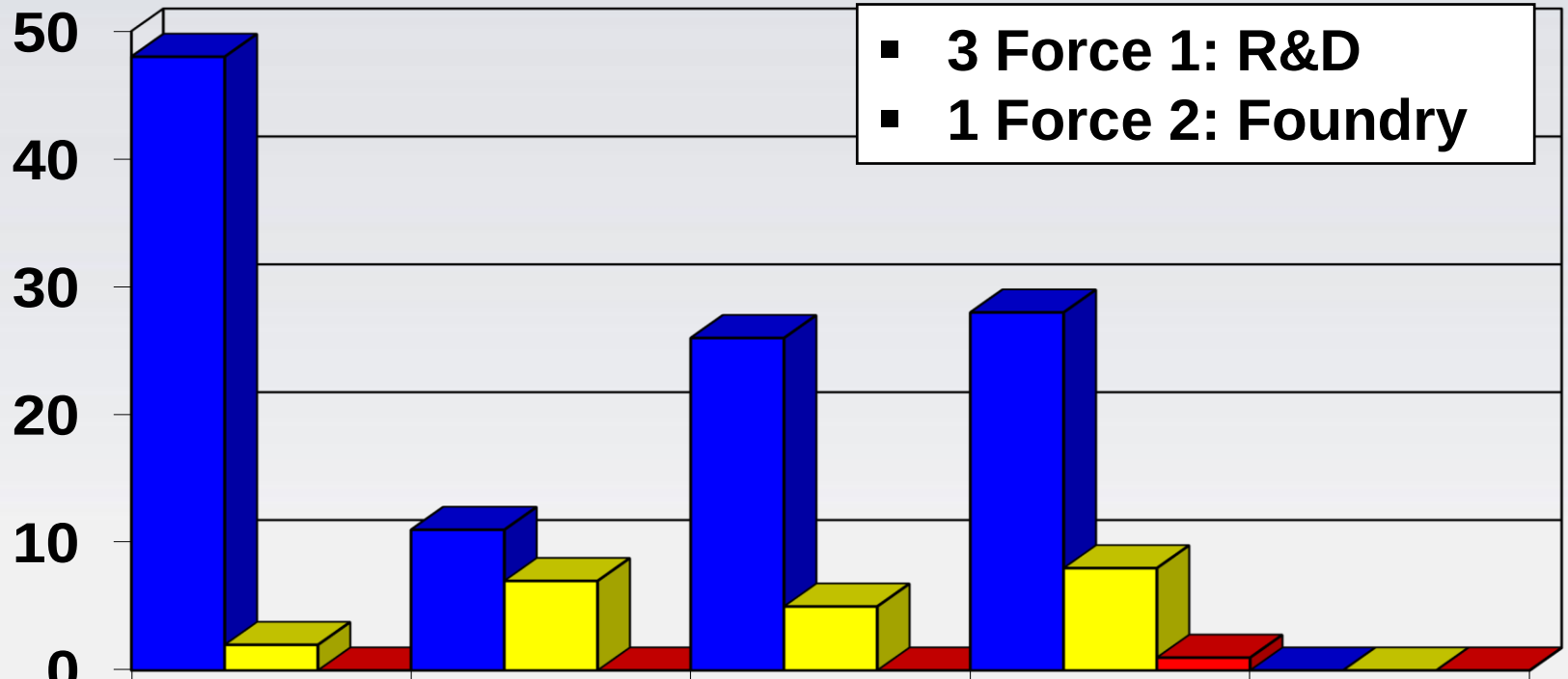


FIGURE 35. Casting EXPLOSIONS by Month 2017 – 2021 **Sep. 2022**

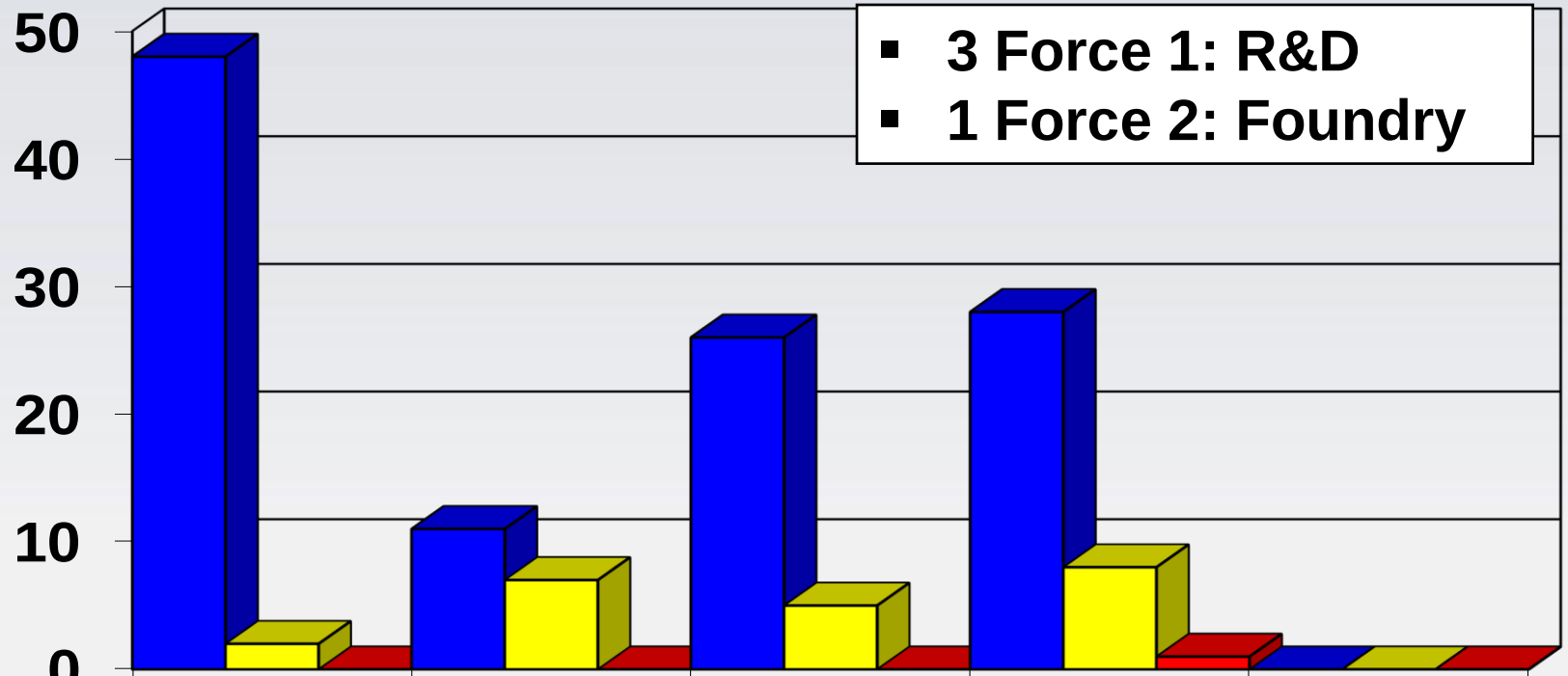
Force Level by Process Plant - 2021



	Reduc-tion	Extru-sion	Rolling	Recycl-ing	Forg-ing
Force 1	48	11	26	28	0
Force 2	2	7	5	8	0
Force 3	0	0	0	1	0

FIGURE 37. FORCE LEVEL BY PROCESS PLANT REPORTED FOR 2021 Sep. 2022

Force Level by Process Plant - 2021



	Reduc-tion	Extru-sion	Rolling	Recycl-ing	Forg-ing
Force 1	48	11	26	28	0
Force 2	2	7	5	8	0
Force 3	0	0	0	1	0

FIGURE 37. FORCE LEVEL BY PROCESS PLANT REPORTED FOR 2021 Sep. 2022

Reduction Plant
Main Causes of 51 Incidents - 2021

Melting Incidents	Casting Incidents
1 - Wet Charge: Scrap / Sow	26 - Sow Casting - Cracked, Wet or Rusty Molds
1 - Wet Mg	2 – VDC Start-Up – Wet Equipment 1 - Start-Up – Wet Refractory 1 – Start-up – Wet Starting Block 1 – Start-up SOP Not Adapted or Not Respected
	2 – Termination – Wet Hand Tool 1 – Termination – Wet Drain Pan

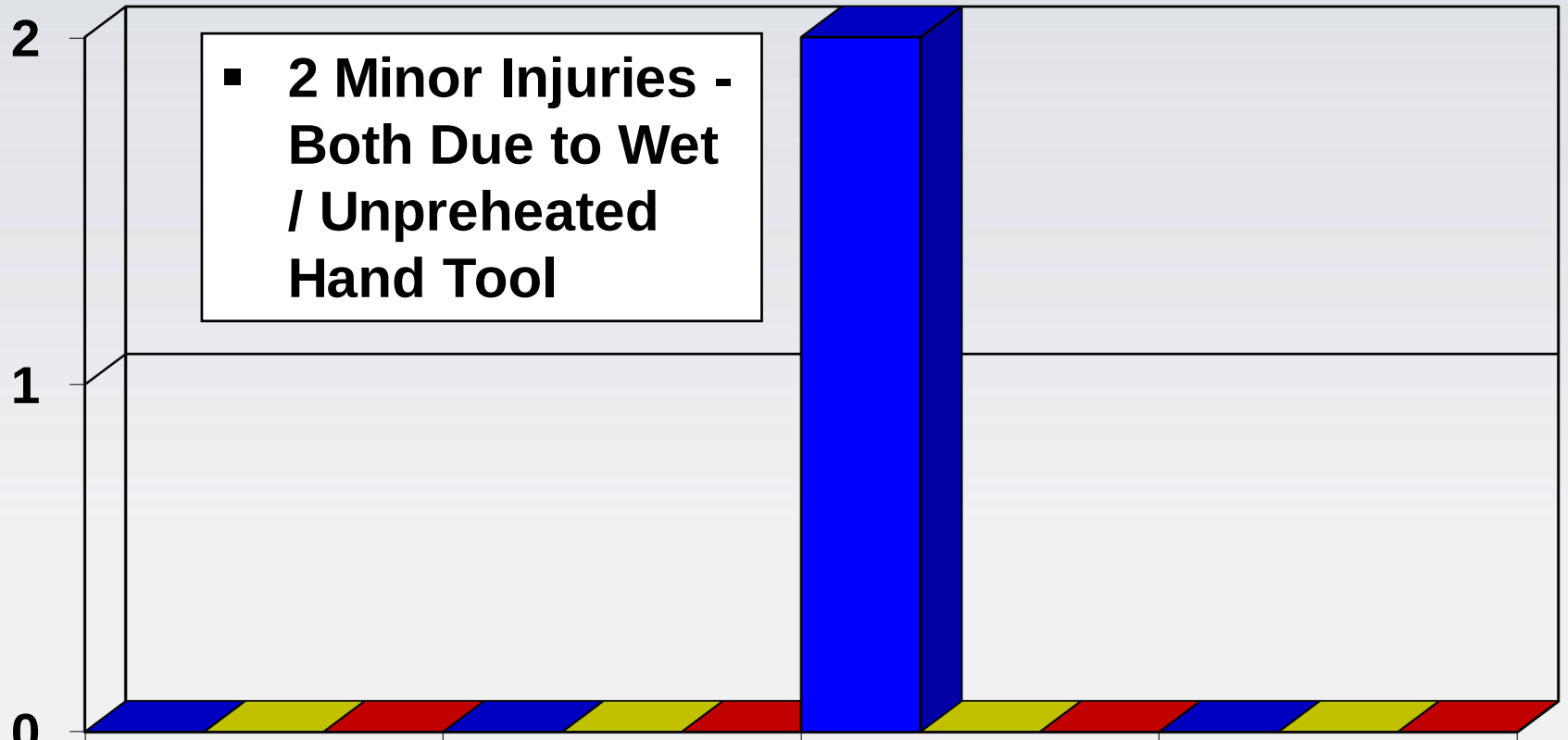
FIGURE 39. REDUCTION PLANT INCIDENTS SUMMARY 2021 Sep. 2022

Reduction Plant
Main Causes of 66 Incidents – 2021

Transfer Incidents	Reduction Cell
5 - Wet / Rusty Tools / Equipmnet	4 – Wet or Rusty Equipment / Drain Pan – Cryolite Transfer
4 - Wet / Rusty Sample Mold / Hand Tool	
2 – Wet / Rusty Drain Pan	

FIGURE 40. REDUCTION PLANT INCIDENTS SUMMARY 2021 Sep. 2022

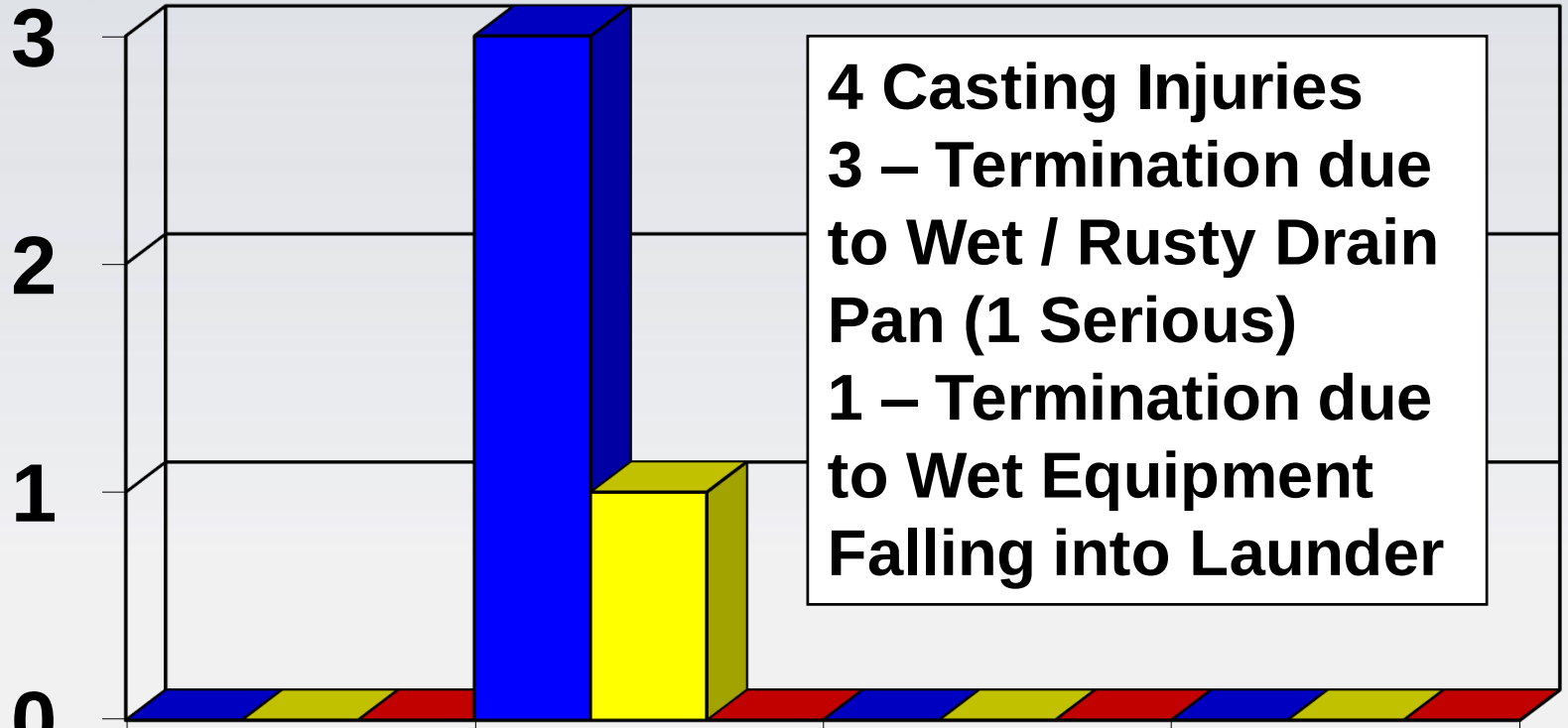
Reduction Plant Injuries & Incident Causes - 2021



	Melting	Casting	Transfer	Other
Minor	0	0	2	0
Serious	0	0	0	0
Fatal	0	0	0	0

FIGURE 41. REDUCTION PLANT INJURIES BY OPERATION 2021 Sep. 2022

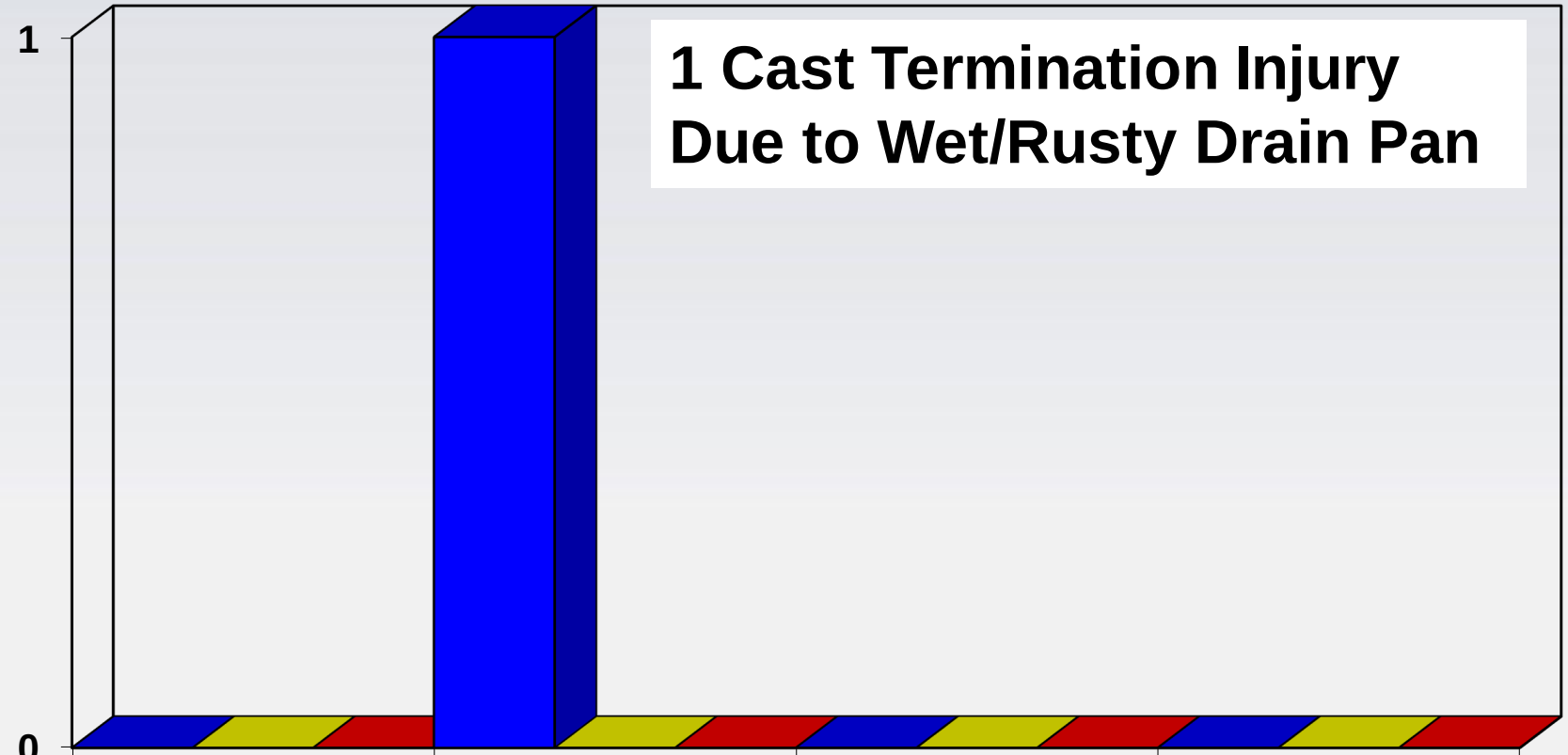
Rolling Plant Injuries - 2021



	Melting	Casting	Transfer	Other
Minor	0	3	0	0
Serious	0	1	0	0
Fatal	0	0	0	0

FIGURE 42. ROLLING PLANT INJURIES BY OPERATION 2021 Sep. 2022

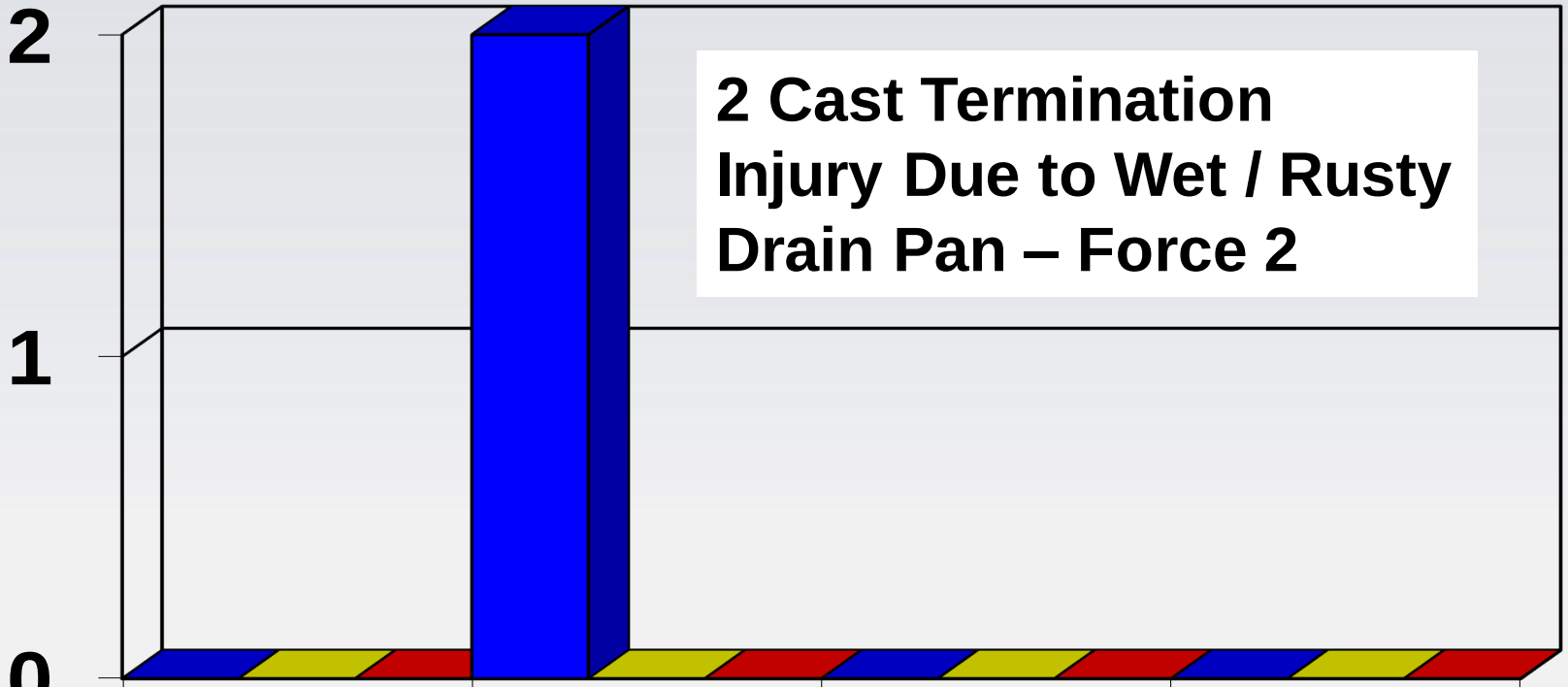
Extrusion Plant Injuries - 2021



	Melting	Casting	Transfer	Other
Minor	0	1	0	0
Serious	0	0	0	0
Fatal	0	0	0	0

FIGURE 43. EXTRUSION PLANT INJURIES BY OPERATION 2021 Sep. 2022

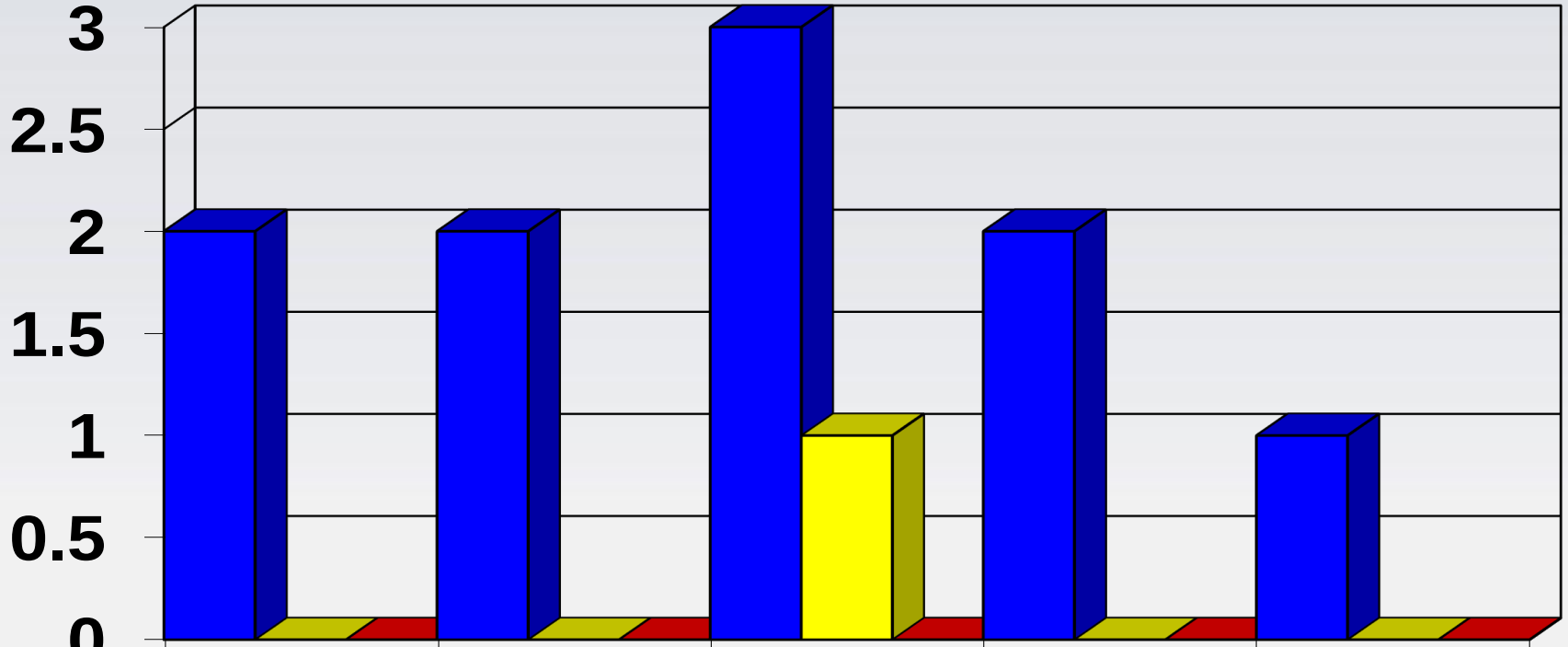
Recycling Plant Injuries - 2021



	Melting	Casting	Transfer	Other
Minor	0	2	0	0
Serious	0	0	0	0
Fatal	0	0	0	0

FIGURE 44. RECYCLING PLANT INJURIES BY OPERATION 2021 Sep. 2022

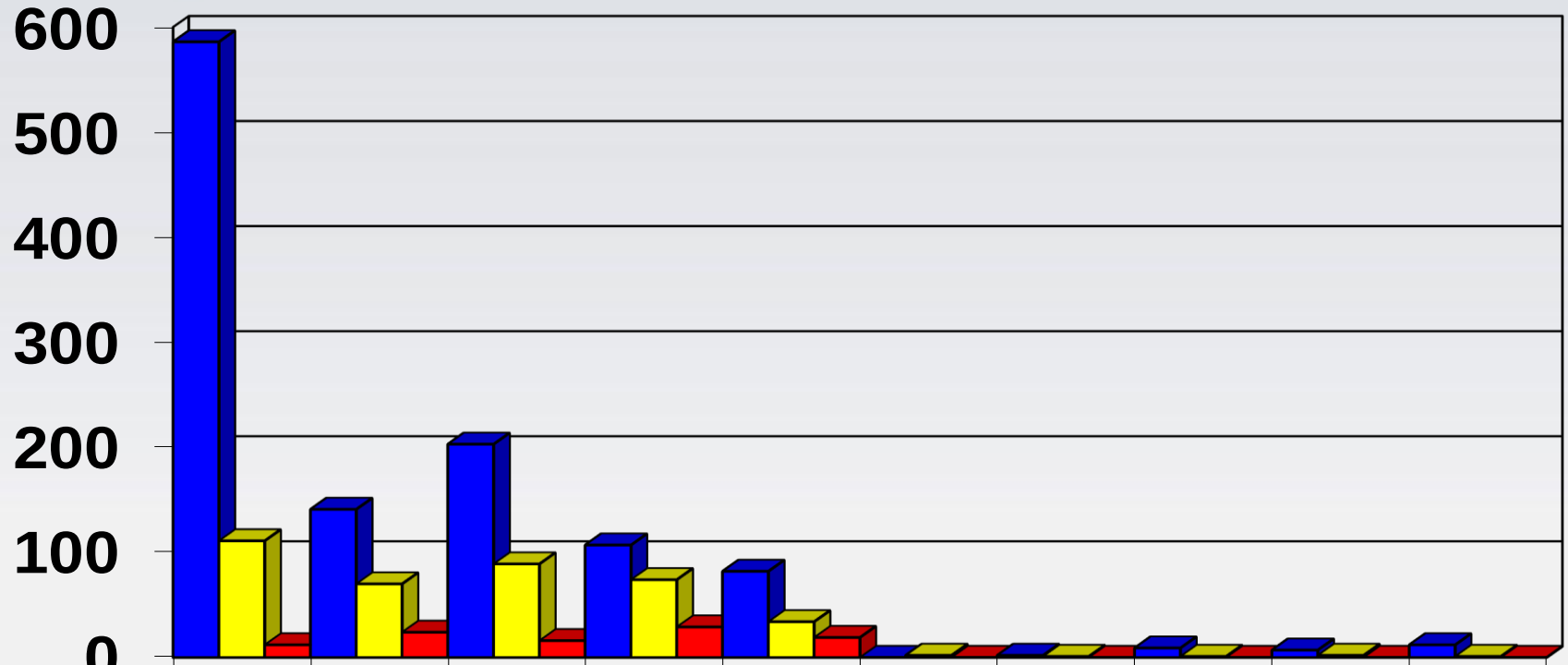
Injury Severity by Process Plant - 2021



	Reduc-tion	Extru-sion	Rolling	Recyling	Other
Minor	2	2	3	2	1
Serious	0	0	1	0	0
Fatals	0	0	0	0	0

FIGURE 45. INJURY SEVERITY BY PROCESS PLANT - 2021 Sep. 2022

Injury Severity by Process Plant 1980 to 2021



	Reduction	Extrusion	Rolling	Recycling	Foundry	Atomizing	Alloying	BRW	Other	R&D
Minor	586	141	203	107	82	0	2	9	7	12
Serious	111	70	89	74	34	2	1	1	2	1
Fatal	12	24	16	29	19	0	0	0	0	0

FIGURE 46. INJURIES BY PLANT REPORTED FOR 1980 - 2021 Sep. 2022

ALUMINUM ASSOCIATION
MOLTEN METAL INCIDENT REPORT

Date of Incident: _____ (month/year) Predominant Plant Activity: SELECT ONE: _____

Explosion Force – Mark One: Force **1** Characterization: ☐ Force **2** Characterization: ☐ Force **3** Characterization: ☐

For definition of force, click arrow to see a description

Alloy Metal Temperature ☐ °F ☐ °C Approximate Amount of Metal Involved ☐ lbs ☐ kilograms

OPERATION:

Charging / Melting Type of Furnace SELECT ONE: _____

Furnace Capacity _____ ☐ lbs ☐ mt % Full _____

Materials Charged _____

Outside Storage? Yes ☐ No ☐ Preheat? Yes ☐ No ☐ Preheat Time/Temp: _____ hrs ☐ °F ☐ °C

Transfer Type SELECT ONE: _____

Casting Type SELECT ONE: Type of Product being Cast:
SELECT ONE: _____

Stage of Operation: SELECT ONE: _____

Other Describe _____

_____

Number of Injuries by Type: Minor _____ **Severe** _____ **Fatal** _____

Provide a brief description of the incident and its root cause(s): _____

_____

_____

_____

_____

If Charging/Melting Incident, please select appropriate Primary and Secondary cause(s):	**If Transfer Incident, please select appropriate Primary and Secondary cause(s):**	**If Casting Incident, please select appropriate Primary and Secondary cause(s):**
Other Other If Contaminations (other than moisture) was selected, please specify: SELECT ONE:	PRIMARY CAUSE: SECONDARY CAUSE:	PRIMARY CAUSE: SECONDARY CAUSE: If Bleed-out/Bleed-over is selected above, describe reason for Bleed-out or Bleed-Over: _____ If Explosion due to Bleed-out/Bleed-over was selected above, where was the location of Explosions: SELECT ONE: If Metal Level Control Problem was selected above, please specify location of problem: SELECT ONE:

Please return to:

Curt Wells

Director, Regulatory Affairs
The Aluminum Association.
1400 Crystal Drive, Suite 430
Arlington, VA 22202