EDT
Forensic Engineering & Consulting

HFD6062-85199

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Supplemental Report

CONFIDENTIAL

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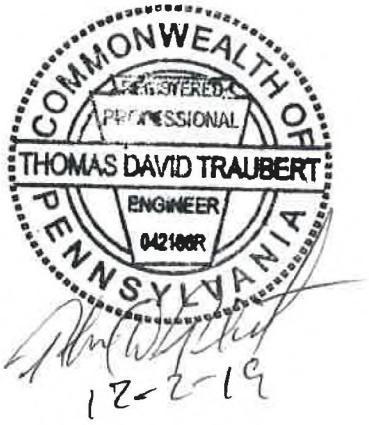

December 2, 2019

REFERENCE: US Steel – No. 2 Control Room Deluge Piping Evaluation
Insured: US Steel
Location of Incident: Clairton, Pennsylvania
Date of Incident: December 24, 2018
Sedgwick File Number: PGH19110240
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The following is a report concerning a technical investigation of an incident involving a coke oven gas processing system at a metallurgical coke plant owned by U. S. Steel, located in Clairton, Pennsylvania. On December 24, 2018, a fire took place in a location known as No. 2 Control Room, where the coke oven gas is processed. A report detailing the findings of the origin and cause of the fire was issued by Engineering Design & Testing on May 10, 2019. The purpose of this report is to address questions regarding piping associated with a fire deluge system that had fallen in the No. 2 Control Room, initiating the incident that took place in December 2018.

The conclusions and opinions stated herein are based on information available to the investigation as of this writing. It is conceivable that additional information may be forthcoming, which bears on these conclusions and opinions. Therefore, the right is reserved to review and modify all conclusions and opinions at any future point in time should, in fact, additional information become available.

For ease of reading and convenience in presentation, this report has been divided into the following sections:

1. Background Information and Work of Investigation
2. Observations – System Design & Site Photographs
3. Observations – Deluge Piping Components (EDT Lab)
4. Deluge System Inspection & Maintenance
5. Discussion
6. Conclusions

Figures

Appendices

I. Deluge System at No. 2 Control Room and Post Incident Site Photographs

A. Background Information and Work of Investigation

U. S. Steel (USS) owns and operates a facility that produces metallurgical coke, known as Mon Valley Works – Clairton Plant (the Clairton Plant), located in Clairton, Pennsylvania. On December 24, 2018, a fire took place in a location known as No. 2 Control Room, where purification of coke oven gas, a byproduct of coke production, takes place. Engineering Design & Testing (EDT) issued a report, dated May 10, 2019, that identified the origin and cause of the fire.[1]

Engineering Design and Testing determined that the incident initiated when a section of fire suppression (deluge) piping fell from the ceiling in the No. 2 Control Room, severing a lube oil supply pipe to one of the vacuum machines (C-521). Severing of the lube oil pipe then initiated a series of events that resulted in a lube oil fire, fracture of a shaft on the first stage of the vacuum machine, and excessive vibration that opened a pipe flange, releasing flammable gas. The large flow of gas served as the primary fuel source, which was ignited by the already burning lube oil.

A number of questions regarding the potential for third party liability, with regard to the design and/or maintenance of the deluge system, have arisen after the report had been issued by EDT. In this regard, the purpose of this report is to provide further details concerning the condition of the deluge system at the time of the incident. Furthermore, USS procedures for the inspection and maintenance of the deluge system are addressed, with regard to third party involvement.

The No. 2 Control Room was constructed circa 1966, therefore limited information was available concerning parties responsible for the design and installation of the deluge system. Nonetheless, EDT reviewed an original installation drawing, then compared the drawing to photographs taken of the deluge system, post incident. The locations of key piping components involved in the incident are identified on the drawing, as well as in the photographs. In this regard, a portion of the installation drawing, along with site photographs taken post incident, is attached as Appendix I to this report.

USS personnel responsible for the testing, inspection and maintenance of the deluge system were interviewed with regard to frequency of the testing/inspection, as well as any recent significant findings with regard to maintenance issues. USS inspection and test reports for 2017 and 2018 were provided for review, along with an inspection report prepared by a third party in 2003. The reports are not attached to this report, but remain a part of the file in this matter. USS personnel discussed the procedure for conducting maintenance work on the deluge system, including providing the name of the current outside (third party) vendor responsible for maintenance.

The deluge piping and fractured coupling section involved in the incident (found at C-521) had been retained and tested by US Steel Research. The components were shipped to EDT for

[1] For reference, the report describes in detail the systems and equipment used to purify the coke oven gas.

further evaluation with regard to conditions expected to result in a loss of mechanical integrity. In this regard, relevant photographs of the piping and coupling are attached as Figures 1 through 9. The results of a metallurgical evaluation of the piping and coupling, conducted by US Steel Research, are summarized.

Sections of the National Fire Protection Association (NFPA) Code were reviewed with regard to the required frequency and scope of inspections and testing of fire deluge systems.

Based upon discussions with USS personnel and review of documents associated with the deluge system in the No. 2 Control Room, EDT determined the most probable progression and cause for detachment of the deluge piping, as well as identification of any third party responsible for the incident.

B. Observations – System Design & Site Photographs

Reference here is to an original installation drawing for the deluge system, followed by a series of photographs attached as Appendix I. The drawing depicts the portion of the deluge system located above the general vicinity of C-521 (origin of fire), while the photographs show the positions of various sections of the deluge piping, post incident.

Deluge System Drawing – Deluge Piping Above C-521 and C-524

1. The drawing in Appendix I shows the portion of the deluge system piping above, and in the vicinity of C-521 and C-524, as viewed from above the No. 2 Control Room ceiling. A number of piping sections shown on the drawing are identified to provide a frame of reference, relative to the photographs. The drawing is referenced again in Section E of this report with regard to the sequence of piping detachment.

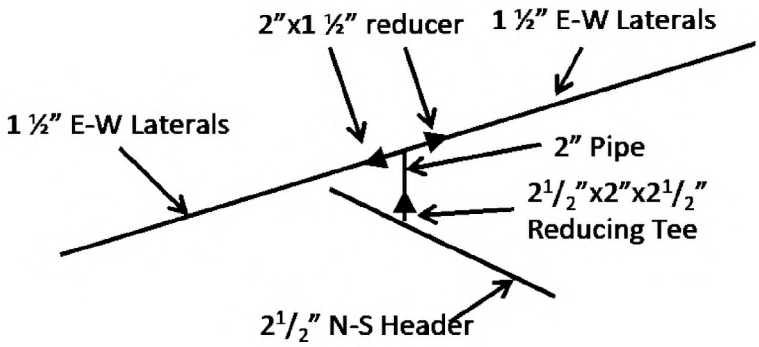
2. The deluge system above the vacuum machines is divided into a north and south section. Pipe Section "A" (blue color bubble), located just north of Truss 10, is an east-west lateral that is attached to the north end of the south section of the deluge system. Pipe Sections "B" and "C" (green and purple color bubble, respectively) were attached to the south end of the north section of the deluge system. The north section is supplied with water by a 6-inch pipe that originates at a control valve station, located at the far south end of No. 2 Control Room. The 6-inch pipe is connected by a series of flanges, one of which had separated at the time of the incident (identified as *6" Flange Separated* on drawing). The north end of the 6-inch pipe that had been connected to the 6-inch flange had bent upward at the time of the incident.

3. Post incident, Pipe Section "C" was found lodged against the lube oil supply pipe for the second stage of C-521 (having severed the lube oil supply pipe), while Pipe Section "D" was found on top of the first stage of C-524. Pipe Section "E" (red color bubble) was found against the north side of the C-521 drive motor and laying atop the C-518 drive motor.

4. The south end of the north section of the deluge system is supplied by a 4-inch header that reduces to a 3-inch header at the approximate mid-point of Pipe Section "E". The 3 inch portion of the header continues through Pipe Section "D", where at the south end, a fitting known as a reducing tee (3"x2"x2½") is used to transition the header from a 3-inch to 2 ½-inch header, which forms the beginning of Pipe Section "C".[2]

5. The transition from the 2½ inch header at Pipe Section "C" to the laterals is provided by a 2 inch by 2½ inch by 2 inch reducing tee fitting (2"x2½"x2" reducing tee), with the 2 inch portion of the tee feeding the laterals (refer to sketch on the next page).

[2] Reducing Tee fittings are designated by the size of the header inlet by branch by header outlet; a 3"x2"x2½" reducing tee has 3-inch header inlet with a 2-inch branch connection and a 2½ inch header outlet connection.



6. A 4"x2"x4" reducing tee that had experienced severe thinning, due to corrosion, (identified as corroded 4"x2"x4" reducing tee on the drawing) was found near C-521. Given the configuration of the deluge piping shown on the installation drawing, all indications are that the 4"x2"x4" reducing tee was attached to the north end of Pipe Section "E".

7. A portion of the roof for No. 2 Control Room had experienced a collapse between support Truss 9 and 10 (identified on the drawing as Hole in Roof).

Deluge System – Post Incident Photographs

8. Photograph 1 shows a portion of the roof for No. 2 Control Room, located south of C-521, that had experienced collapse between the trusses for column 9 and 10. Vacuum machines C-524 and C-527 are located beneath the portion of the roof that had experienced the collapse. For reference, the north-most east-west lateral for the south section of the deluge system, is identified as Pipe Section "A". Further reference points to the deluge system drawing are identified by Pipe Section "B", which remained suspended after Pipe Section "C" had detached and fell on C-521, and the separated 6-inch pipe (6" Pipe Bent Upward/6" Flange Separated). The separation and deformation experienced by the 6-inch pipe is the result of the high temperatures associated with the fire.

9. A closer view of Pipe Section "A" and the 6" separated flange is shown in Photograph 2. Note the deformation experienced by Pipe Section "A", indicative of high temperatures associated with the fire. Separation of the pipe at the 6-inch flange took place at the threaded joint between the pipe and flange due to high strains associated with the upward deformation of the north end of the 6-inch pipe.

10. Photograph 3 shows a closer view of Pipe Section "B", having experienced severe deformation consistent with exposure to high temperatures. Note the severe deformation experienced by the structural members that comprised the ceiling for No. 2 Control Room.

11. The detached Pipe Section "C", as found at C-521, is shown in Photographs 4 and 5. Later examination of the 2½ inch header revealed an impact location near the detached threaded end, consistent with striking a piece of equipment known as a centrifuge, shown

in Photograph 5. Detailed photographs that confirm Pipe Section "C" had severed the lube oil pipe to C-521 are provided in the origin and cause report prepared by EDT.

12. Pipe Section "C" at USS Research is shown in Photograph 6, with the expected attachment locations identified for Pipe Section "B", and the 3"x2"x2½" reducing tee for the transition from Pipe Section "D". Pipe Section "C" is comprised of the 2½ inch header with an elbow attached at the end of the header, which transitions to the 2-inch east-west laterals using a 2"x2½"x2" reducing tee. A 2 inch by 1½ inch reducer is used to transition between the 2-inch pipe and the 1½ inch laterals. The location of the impact, discussed in the previous observation, is identified on the photograph.

13. Pipe Section "D" as found post incident, laying on the first stage of C-524, is shown in Photograph 7. A C-Clamp type hanger (the hanger), used to suspend the pipe from steelwork in the ceiling, had experienced an overload consistent with the application of a force greater than the design of the hanger.

14. Photographs 8 and 9 show the position of Pipe Section "E", as found during the site visit conducted by EDT, having been relocated between C-521 second stage and the drive motor. The pipe had been relocated in order to remove and repair the C-518 motor. In order to transport the pipe to USS Research, the portion of the pipe shown in Photograph 8 was detached from a 4 inch by 3-inch reducer fitting (4"x3" Reducer).

15. The position of Pipe Section "E", at the time of the incident, is shown in Photographs 10 through 14, having fallen so as to result in the 4 inch piping being lodged against the north side of the C-521 motor, with the 3 inch section of the piping resting on top of the east end of the C-518 motor. The C-Clamp hanger (the hanger) used to suspend Pipe Section "E" had experienced an overload consistent with the application of a force greater than the design of the hanger.

16. The two pieces of Pipe Section "E", at USS Research are shown in Photograph 15, with the overload damage to the hanger identified. The 4-inch pipe had been disconnected at the 4"x2"x4" reducing tee to facilitate shipment to USS Research.

17. The corroded 4"x2"x4" reducing tee, found near C-521, is shown in Photographs 16 and 17, having experienced a ductile overload fracture due to severe corrosion/thinning of a portion of the wall of the tee. Note that the USS Research metallurgical report refers to the reducing tee as a coupling.

C. Observations – Deluge Piping Components (EDT Lab)

The piping components examined by USS Research were provided to EDT for a physical examination. Observations related to said physical examination are provided as follows, and attached in the Figures section of this report:

18. Pipe Section "C" is shown in Figure 1, with the intended attachment points for Pipe Section "B" and "D" identified by Arrow 1 and 2, respectively. The location of impact, between the threaded end of the 2½ inch header and the centrifuge is identified by Arrow 3. The deformation experienced by the header, identified by Arrows 4, took place after the pipe at fallen, due to the temperatures associated with the fire at C-521. Similar deformation had been experienced by the C-Clamp hanger still attached to the header, identified by Arrow 5. Note that the header had been cut, and the elbow to header joint disconnected (by US Steel Research) in order to facilitate shipment of the deluge pipes to EDT.

19. The threaded end of the header, intended to be attached to Pipe Section "D", is shown in Figure 2, with the impact location identified by Arrow 1. The deformation experienced by the threads, identified by Arrow 2 (compressive bending) and Arrow 3 (tensile bending), indicates the orientation of the header at the time that the header fell: The location that had experienced the compressive bending (Arrow 2) is on the bottom of the pipe (facing the floor). Likewise, the location that had experienced the tensile bending (Arrow 3) is on the top of the pipe (facing the ceiling). As the header fell, while still attached to Pipe Section "D", compressive bending took place on the bottom half of the header, resulting in the observed deformation at the threads. At some point, the bending deformation at the threads became sufficient to result in separation between header and Pipe Section "D". Given the observed deformation to the threaded end of the header, the location of the impact is approximately near the top side of the header.

20. Post incident photographs of Pipe Section "C" indicate that the threaded end of the header (intended to be attached to Pipe Section "D") came to rest near the centrifuge shown in Figure 3. The impact damage experienced at the threaded end of Pipe Section "C" is consistent with striking an eye bolt on the centrifuge, identified by Arrow 1, and/or a drive motor housing or other component, identified by Arrow 2.[3]

21. Pipe Section "E" is shown in Figure 4, with Arrow 1 and 2 identifying the 4-inch pipe and 4"x2"x4" reducing tee. The $1^1/_2$"x2"x$1^1/_2$" reducing tee, used to transition the piping to the laterals, is identified by Arrow 3. The reducing fitting used to transition from the 4 inches

[3] The original investigation conducted by EDT evaluated the possibility that fracture of the shaft on C-521 preceded detachment of the deluge pipe when a liberated coupling component struck the deluge pipe, dislodging the deluge pipe. Although the impact located near the threaded end of Pipe Section "C" would appear to support dislodging of the deluge pipe due to an external impact, the operating data does not support such an event sequence. Furthermore, the orientation of the impact and the deformation of the threaded end suggests the impact took place post detachment of the pipe section, due to impact with the centrifuge.

to 3-inch piping is identified by Arrow 4, with the 3-inch piping identified by Arrow 5. The 3-inch piping had experienced deformation due to the heat associated with the fire, after falling. Note that the 4-inch pipe had been detached at the reducing tee, and the 3-inch pipe cut to facilitate shipment to EDT.

22. The C-Clamp type hanger (the hanger) used to suspend Pipe Section "E" is shown in Figure 5, having experienced an overload, similar to the overload experienced by Pipe Section "D".

23. The corroded 4"x2"x4" reducing tee is shown in Figure 6 through 11. A view of the bottom of the reducing tee is shown in Figure 6, with the underside (6 o'clock position) identified by Arrow 1, and the 4-inch inlet and outlet identified by Arrows 2. The reducing tee had experienced through wall corrosion and ductile tearing, identified by Arrow 3.

24. The top side (2-inch branch) of the reducing tee is shown in Figure 7, with the 4-inch inlet and outlet identified by Arrows 1. The approximate location of the corroded and crushed portion of the 2-inch branch is identified by Arrow 2. The corrosion experienced by the top portion of the reducing tee is best described as extensive, with very little metal remaining.

25. Figure 8 shows the corroded reducing tee joined to a threaded portion of 4-inch pipe that comprised Pipe Section "E", confirming the inlet and outlet size of the reducing tee to be 4 inches.

26. The corroded reducing tee was placed next to the 4"x2"x4" reducing tee comprising Pipe Section "E" as shown in Figure 9, further confirming that the corroded reducing tee is a 4"x2"x4" reducing tee, intended to be attached to the north end of Pipe Section "E".

D. Deluge System Inspection & Maintenance

Deluge System History

The deluge system was installed during the construction of the No. 2 Control Room, circa late 1960s. The original installation drawing for the deluge system informs that the deluge system was designed by the Blaw-Knox Company, Auto Sprinkler Department.[4] The latest revision block on the drawing informs that the drawing was issued in November 1967. USS reported that no changes (of record) have been made to the original installation of the deluge system. Examination of the post incident photographs confirmed that the portion of the deluge system near C-521 is consistent with the configuration shown on the original installation drawing, thus supportive of USS reports with regard to changes to the deluge system.

The deluge system is known as a dry system, whereby water is not present inside the piping above the vacuum machines. The fire water supply to the north and south sections is controlled by two control valves (one for each section) that are opened by manual activation of a pull station, located at the south end of the No. 2 Control Room.

Deluge System Inspection and Testing

Mr. Aaron Gilbert, Fire Chief with USS, reported that the deluge system is inspected and trip tested by USS fire department personnel every year, with a report generated to document said inspection/testing. However, the testing does not involve filling of the piping above the vacuum machines, i.e., a full discharge test. The test is conducted by first opening a drain valve located downstream of the control valves, then tripping the system to verify the operation of a pressure switch used to indicate the presence of water flow into vertical pipes (known as risers), that connect to the north and south sections of the system. The system is shutdown prior to water accumulating to any significant amount inside the risers. USS is not aware of any time, since the original installation, that the deluge system above the vacuum machines had been activated, other than during the incident/fire that took place in December 2018.

In addition to the trip test, a visual inspection of the deluge system components and piping is conducted. It is noteworthy that the deluge system headers and laterals are located approximately 45 feet above the floor vacuum machine operating floor. As such, a detailed/close-up visual examination is not feasible. In fact, a review of the inspection reports for 2017 and 2018 inform that the pipe support hangers were not checked in 2018, but were checked in 2017, from the floor level only. Mr. Gilbert clarified the apparent omission of an inspection indicated in the 2018 report: The inspector had evaluated the deluge system above the vacuum machines from the floor level, but was unable to assess the condition, hence the indicated omission on the inspection form. Given the arrangement of the vacuum machines inside No. 2 Control Room, and the position of the deluge system headers, it is not possible to access the deluge system to the extent required to assess the condition of components

[4] The Blaw-Knox Company Auto Sprinkler Department is no longer in business.

intended to support/suspend the piping. To provide further context with regard to evaluation of the deluge system above the vacuum machines, reference here is to a photograph of the replacement deluge system (installed in 2019), as viewed from the floor:

USS provided a report of the only known detailed inspection of the deluge system at No. 2 Control Room, conducted by Simplex Grinnell (Grinnell) in 2003.[5] The inspection addresses not only the condition of the deluge control valves, but identified a number of locations where piping supports (hangers) were deficient or required replacement. However, the report is silent with regard to the condition of the hangers above the vacuum machines, suggesting that no issues were identified (or that the location of the hangers was such that access could not be attained).

Deluge System Maintenance

Mr. Gilbert reported that any maintenance work identified as a result of USS personnel inspections of the deluge system must be conducted by a certified fire sprinkler contractor. USS have engaged Grunau Corporation (Grunau) in the past to conduct repairs to the control valves

[5] The inspection also included a process location known as No. 1 Control Room.

at the plant from 2014 through 2017. It is unknown who conducted the repairs to hangers recommended in the 2003 inspection, as USS was unable to locate records documenting the repairs. Nonetheless, there is no record of any inspections or subsequent repairs for the portion of the deluge system located above the vacuum machines. Furthermore, USS engages Grunau on an as needed basis when repairs are required to the plant fire protection systems, and does not have an annual contract for ongoing inspection and maintenance services.

E. Discussion

Metallurgical & Physical Evaluation – Deluge Piping

USS Research determined that all of the deluge piping recovered in the location of C-521 had not experienced temperatures sufficient to result in metallurgical changes as would be expected had the piping been present in the ceiling during the fire.[6] As such, it can be concluded that the deluge piping recovered at C-521 had fallen prior to the fire. However, deformation to steel components takes place at temperatures of approximately 1,000 F, which is consistent with temperatures expected near C-521 during the fire. Such was the case with the deformation experienced by Pipe Sections "C" and "E", which after having fallen, had experienced deformation after exposure to high temperatures during the fire. The deformation is the result of decreased strength at the elevated temperatures, whereby the pipe sections deformed under their own weight. In other words, very little external load is needed to deform the piping sections at elevated temperatures.

USS Research had also determined that fracture of the corroded 4"x2"x4" reducing tee (identified as the coupling in the USS report) took place as a result of a ductile overload and was not due to overheating/melting. Said ductile overload resulted when corrosion had compromised the top (2-inch branch) side of the reducing tee, resulting in separation at the 4-inch threaded joints and crushing of what little remained of the top side of the reducing tee.

Sequence of Events – Deluge Piping Detachment

Based upon the prior investigation conducted by EDT, there is no doubt that Pipe Section "C" had fallen and severed the lube oil pipe on C-521. However, the as-installed (in the ceiling) location of the portion of Pipe Section "C" that had impacted the lube oil pipe is approximately 20 feet south of C-521. As such, detachment of the supports associated with Pipe Section "C" took place in a manner so as to result in rotation of the Pipe Section "C" and "D" downward (to the north, toward C-521). In this regard, Pipe Section "D" rotated at about the location where Pipe Section "D" is attached to Pipe Section "E" (about two feet south of C-521). At some point, Pipe Section "C" deflected downward at the threaded joint connected to Pipe Section "D" and separated. The separated Pipe Section "C" struck the lube oil piping on C-521, with the threaded end coming to rest on the centrifuge, while Pipe Section "D" came to rest across C-524.

Given the corroded/deteriorated condition of the 4"x2"x4" reducing tee at the north end of Pipe Section "E", the expected sequence of deluge pipe detachment is as follows (refer to the drawing in Appendix I):

[6] At temperatures greater than approximately 1,300 F, carbon steels undergo microscopic changes (metallurgical changes) that involve the crystalline microstructure, which depending upon the duration at the elevated temperature, and rate of cooling, may affect the mechanical properties of the steels, such as tensile strength and ductility. Given the extended duration of the fire, steel components located in the ceiling during the duration of the fire would be expected to have experienced some degree of metallurgical change.

1. Corrosion at the 4"x2"x4" reducing tee results in separation of the north end of Pipe Section "E" and subsequent overloading of the hanger (C-Clamp hanger) on Pipe Section "E".

2. As Pipe Section "E" detaches, the hanger on Pipe Section "D" is overloaded, resulting in detachment of Pipe Section "D" and pulling of Pipe Section "C" to the north, detaching Pipe Section "C" at the south end laterals. Pipe Section "C" and "D" rotate downward about the connection between Pipe Section "D" and "E"

3. Pipe Section "C" detaches and lands upon the lube oil pipe at C-521, while Pipe Section "D" is thrown to the south, where it comes to rest on C-524.

3. Pipe Section "E" is thrown toward, and lands upon the motors for C-518 and C-521.

Deterioration/Corrosion of Deluge Piping

The aforementioned sequence of events requires some level of deterioration to have been experienced by the hangers on the east-west laterals in addition to deterioration of the 4"x2"x4" reducing tee (at the north end of Pipe Section "E"). In this regard, the 2003 Grinnell inspection report identified missing hangers and hangers requiring replacement in other, more accessible locations at the No. 1 and 2 Control Rooms. A post incident inspection of No. 1 Control Room deluge systems identified a number of missing/loose hangers. An inspection of the deluge system beyond the fire location (south end of No. 2 Control Room) revealed loose hangers and sagging headers, placing a bending strain on the reducing tee fittings. Given the condition of deluge system supports/hangers are of the same vintage as those used in the deluge system above the vacuum machines, and the mechanism necessary for impact of the deluge piping at C-521, all indications are that long-term deterioration had affected the integrity of the hangers/supports that comprised a portion of the deluge system above the vacuum machines, in particular the location above C-521 and C-524.

The extensive corrosion experienced by the 4"x2"x4" reducing tee (the reducing tee) was very localized. The top half of the reducing tee experienced external corrosion to the extent that no metal remained in some locations, transitioning to paper-thin metal near the 2-inch branch and sides of the reducing tee. A number of observations are noteworthy, regarding the corrosion experienced by the reducing tee:

1. The reducing tees, fittings and pipe, comprising the pipe sections that had fallen were absent any level of significant corrosion, both internal and external to the pipe sections.

2. Given the localized corrosion only experienced by the 4"x2"x4" reducing tee, it is more probable than not that the corrosion resulted from a leak in the roof of the No. 2 Control Room. Water, laden with sulfur bearing compounds found in the atmosphere in the plant, dripping upon the top of the reducing tee, formed a corrosive, weak sulfuric acid that produced the very localized corrosion on the top side of the reducing tee. Such

corrosion is common in carbon steel components exposed to the atmosphere in the plant.

3. The corrosion, and resulting extensive metal loss experienced by the reducing tee resulted in the inability to maintain support of Pipe Section "E", thus corrosion of the reducing tee initiated the aforementioned sequence of events.

4. The corrosion experienced by the reducing tee was local to the top side of the reducing tee, rendering the condition of the reducing tee not visible to an inspector viewing the deluge system from the floor of No. 2 Control Room.

Inspection and Maintenance of Deluge System

All inspections of the deluge system are conducted by USS Fire Protection personnel, with any maintenance items identified by the inspections addressed by a third-party contractor. USS reported that no work, either by USS personnel, or a third party had been conducted on the hangers/supports located on the portion of the deluge system above the vacuum machines. The elevation of the deluge system above the vacuum machines prevented USS from conducting a close-up inspection/evaluation of the condition of the hangers/supports. It is noteworthy that USS reported during the demolition and replacement of the existing deluge system, numerous hangers were found loose or not providing adequate support of the piping. Only when the existing deluge system had been accessed close enough to conduct the demolition work, was the condition of the hangers recognized.

NFPA Code Requirements for Inspection of Deluge Systems

A review of the inspection requirements for deluge systems, recommended by the National Fire Protection Association (NFPA) *NFPA 25 Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems*, (the NFPA Code) was conducted. In this regard, Section 5.2.2 & 5.2.3 requires an annual inspection of all hangers, pipes and fittings from the floor level.[7] As such, USS had met the requirements of the NFPA Code, by only conducting a visual evaluation of the deluge system from the floor level of the vacuum building. Given the elevation and position of the deluge system above the vacuum machines said inspection would only identify large displacements in the piping due to multiple hanger failures, and would not identify the corrosion experienced by the top side of the 4"x2"x4" reducing tee.

[7] The NFPA Code also states that piping installed in concealed locations, such as suspended ceilings, does not require inspection. Such a location would be considered inaccessible, which can be deemed similar to the location of the deluge system above the vacuum machines. Furthermore, Section 5.2.2.4 and 5.2.3.4 state that piping, fittings and hangers located in areas that are inaccessible for safety considerations due to process operations shall be inspected during each scheduled shutdown. Section 5.2.2.4 and 5.2.2.4 are not applicable to the deluge system above the vacuum machines since USS does not shutdown all the vacuum machines. Said shutdown results in the production and burning of untreated coke oven gas, which violates the Clairton Plant air emission permit.

Third Party Liability for Incident

Given USS was responsible for the inspection and identification of maintenance required for the deluge system, and no third party had conducted maintenance on the portion of the deluge system involved in the incident, there is no third party that can be held liable for the detachment of the deluge system piping that initiated the incident/fire that took place on December 24, 2018.

F. Conclusions

1. Separation and detachment of the deluge piping took place prior to the fire.

2. The hangers used to suspend the deluge piping had experienced long-term deterioration since installation circa 1967 so as to compromise the load carrying capacity of the hangers.

3. A reducing tee fitting, located in the deluge system main 4-inch supply header, had experienced severe, localized corrosion due to exposure to corrosive water discharged onto the reducing tee as a result of a roof leak.

4. Corrosion and complete loss of metal on the top of the reducing tee resulted in a loss of support, and subsequent separation of the 4-inch supply header, that initiated progressive detachment of the downstream deluge system piping.

5. A portion of the detached deluge system piping struck and severed a lube oil supply pipe to C-521, thus initiating a sequence of events that resulted in the fire as detailed in the prior report issued by EDT in this matter.

6. US Steel was in compliance with requirements set forth by the National Fire Protection Association with regard to the inspection and maintenance of the deluge system.

7. US Steel is responsible for inspection of the deluge system and the identification of work scope requiring maintenance from a third-party contractor, certified to repair fire protection systems.

8. No maintenance (by US Steel or a third party) had been conducted on the portion of the deluge system involved in the incident, since original installation.

9. Absent any third party involvement in the inspection, or maintenance of the specific portion of the deluge system involved in this matter, there is no third party that can be held liable for the detachment of the deluge system piping that initiated the incident/fire that took place on December 24, 2018.

FIGURES

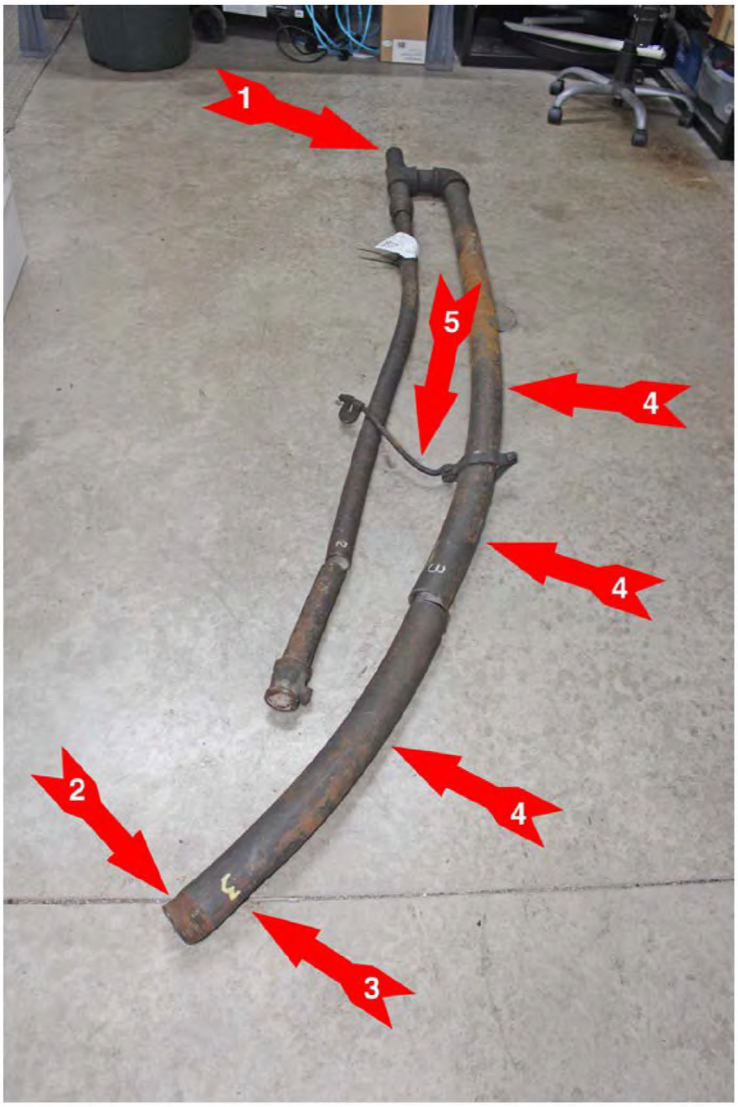


Figure 1	Pipe Section "C"	
	Arrow 1	Pipe Section "B" attachment point
	Arrow 2	Pipe Section "D" attachment point
	Arrow 3	Impact location
	Arrows 4	Deformation due to heat
	Arrow 5	Deformation of hanger due to heat

Figure 2	Threaded end of header	
	Arrow 1	Impact location
	Arrow 2	Compressive bending at threads
	Arrow 3	Tensile bending at threads

Figure 3	Centrifuge near C-521	
	Arrow 1	Eye bolt on centrifuge
	Arrow 2	Damage to centrifuge drive motor housing

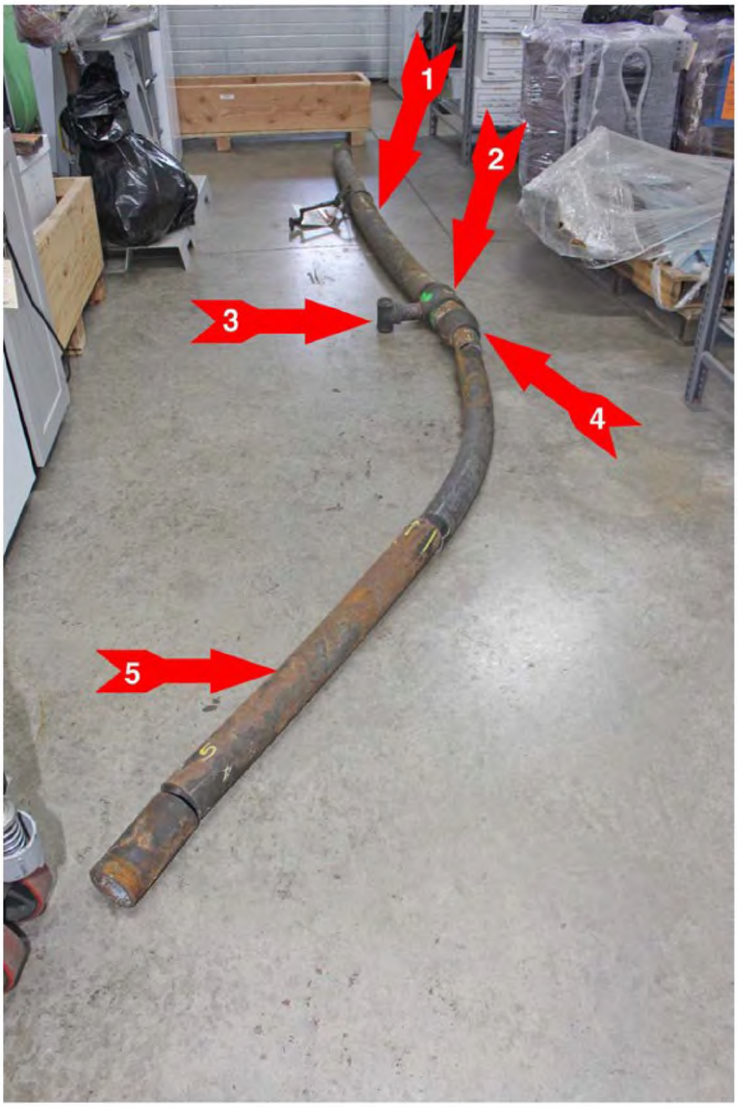


Figure 4	Pipe Section "E"	
	Arrow 1	4-inch pipe
	Arrow 2	4"x2"x4" reducing tee
	Arrow 3	11/2"x2"x11/2" reducing tee
	Arrow 4	4 inch by 3 inch reducing fitting
	Arrow 5	3-inch pipe

Figure 5 Overload deformation to hanger – Pipe Section “E”

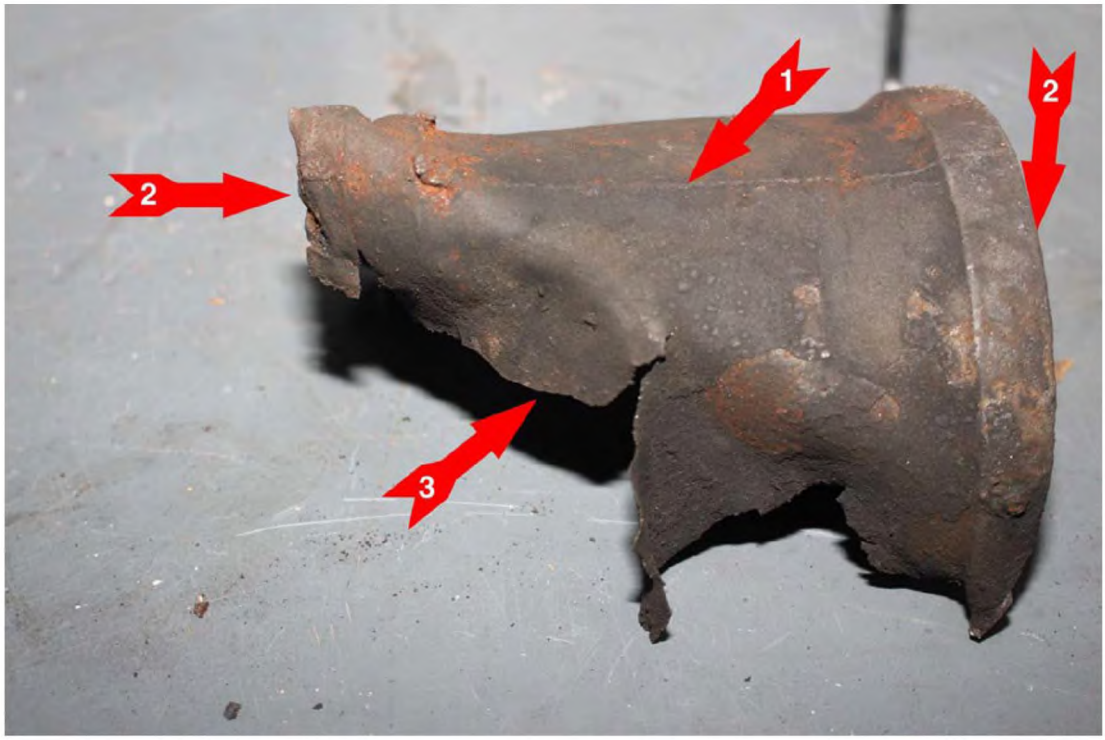


Figure 6	Corroded 4”x2”x4” Reducing Tee	
	Arrow 1	Bottom
	Arrows 2	4-inch inlet and outlet
	Arrow 3	Through-wall corrosion and ductile tearing

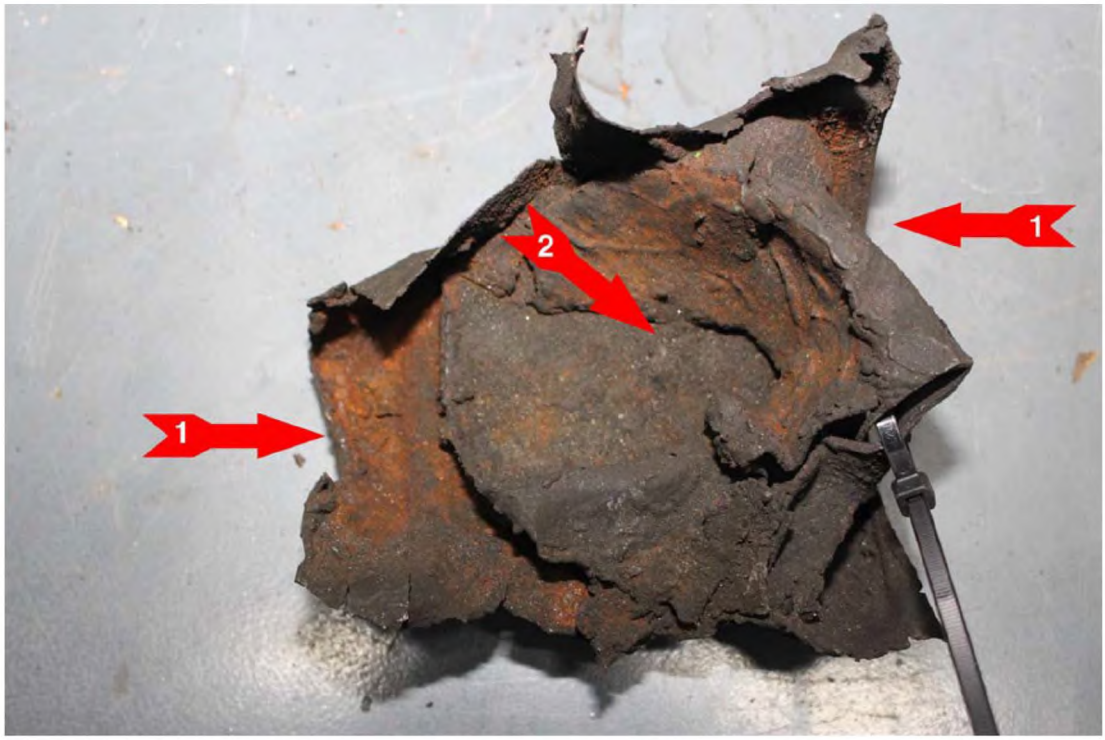


Figure 7	Corroded 4”x2”x4” Reducing Tee	
	Arrows 1	4-inch inlet and outlet
	Arrow 2	Approximate location of 2-inch branch

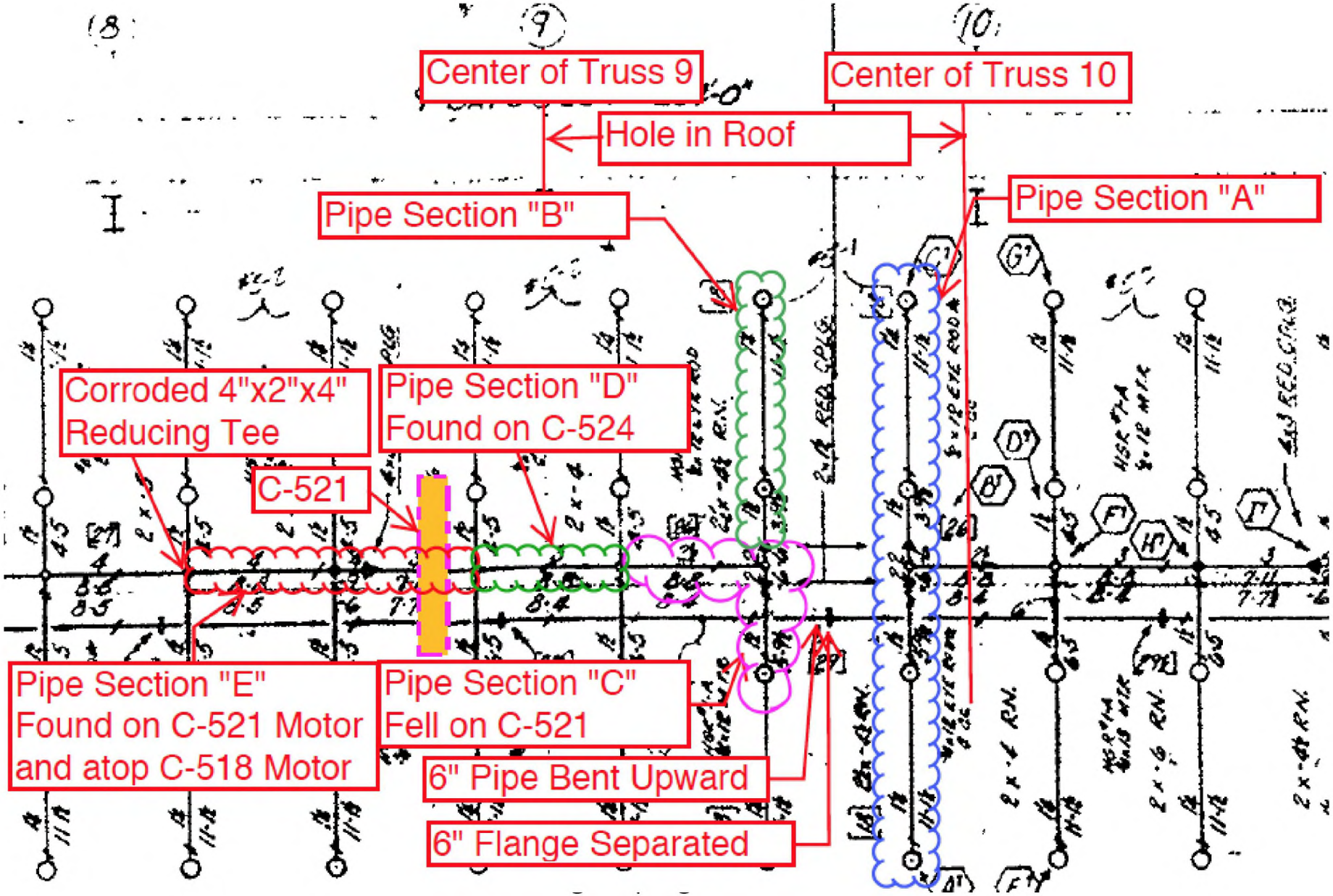
Figure 8 Corroded 4”x2”x4” Reducing Tee attached to 4-inch threaded pipe

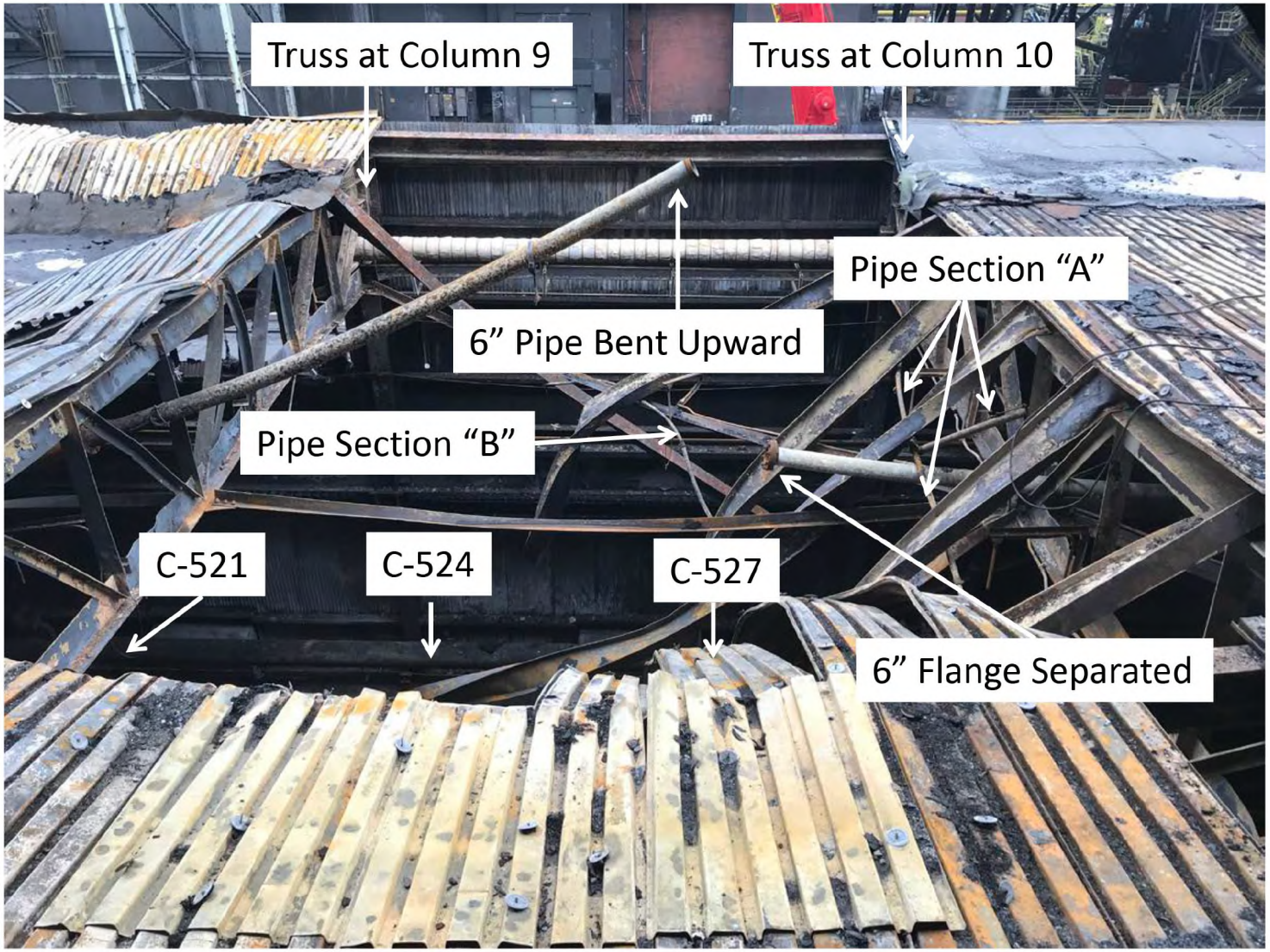
Figure 9 Corroded 4”x2”x4” Reducing Tee placed next to 4”x2”x4” reducing tee comprising Pipe Section “E”

APPENDIX I

Deluge System at No. 2 Control Room and

Post Incident Site Photographs


Center of Truss 9
Center of Truss 10
Hole in Roof
Pipe Section "B"
Pipe Section "A"
Corroded 4"x2"x4"
Reducing Tee
Pipe Section "D"
Found on C-524
C-521
Pipe Section "E"
Found on C-521 Motor
and atop C-518 Motor
Pipe Section "C"
Fell on C-521
6" Pipe Bent Upward
6" Flange Separated



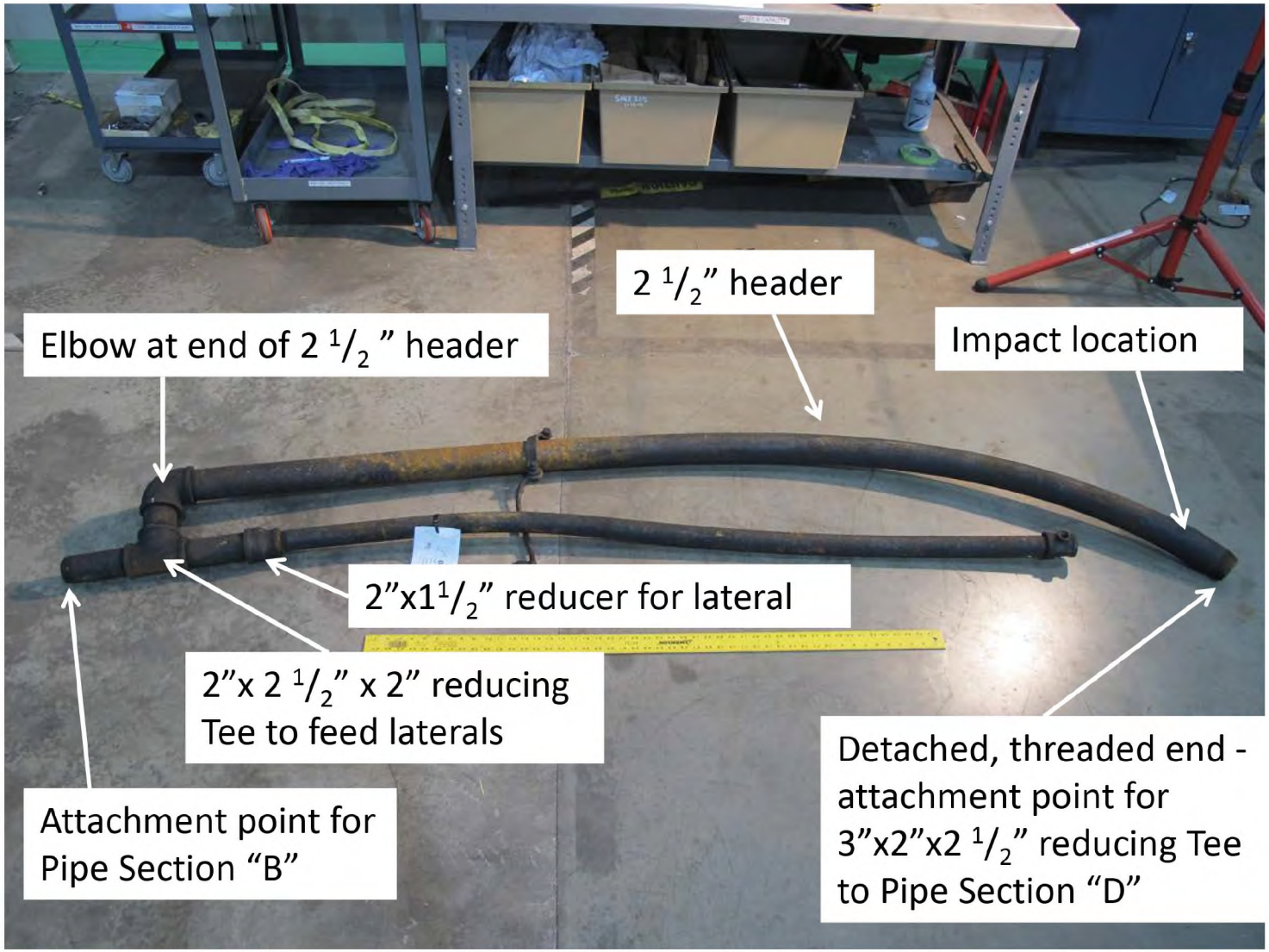
Photograph 1 – Roof Collapse Near C-521

Photograph 2 – Pipe Section “A”

Photograph 3 – Pipe Section “B”

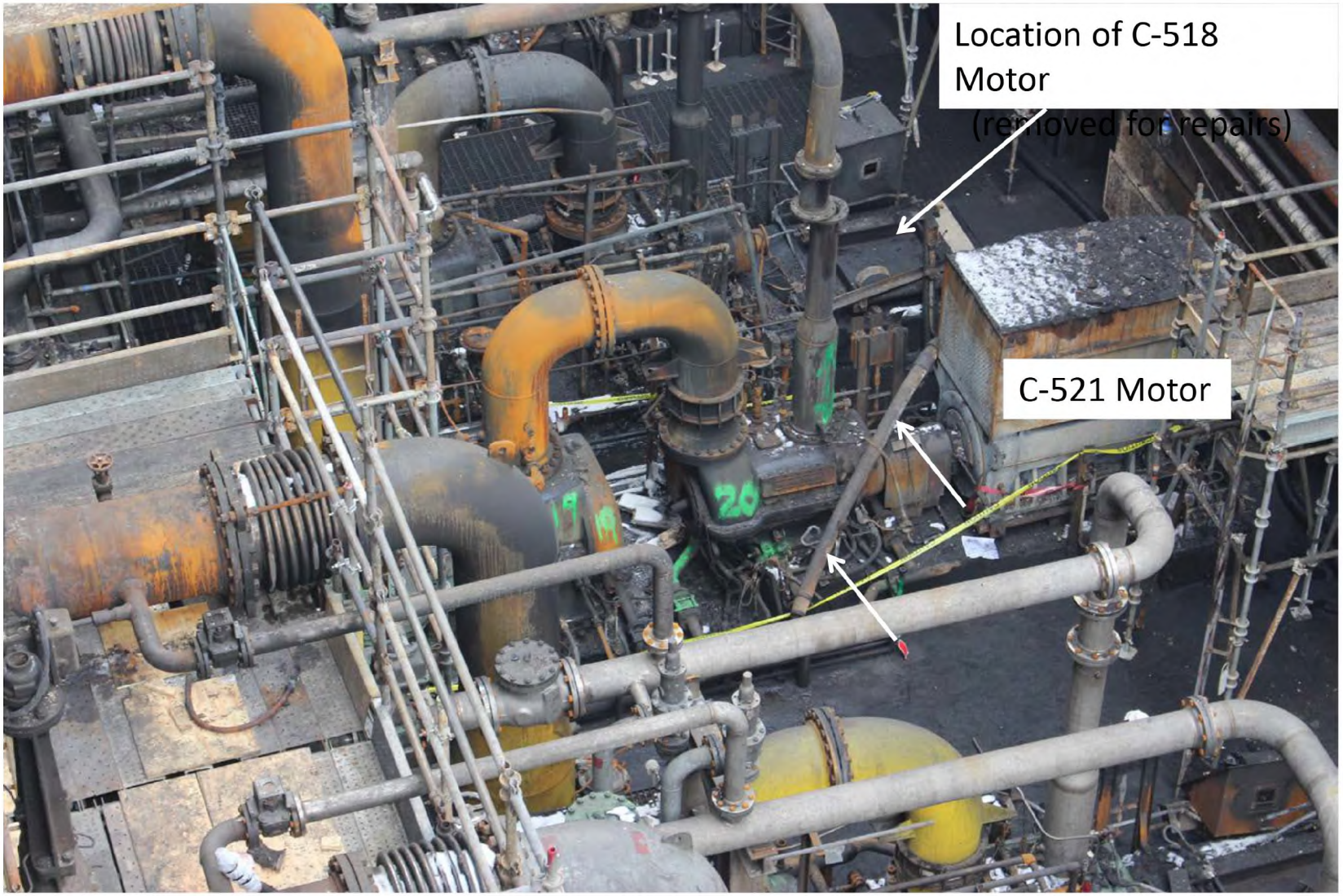
Photograph 4 - Pipe Section “C” – At C-521

Photograph 5 - Pipe Section “C” – At C-521

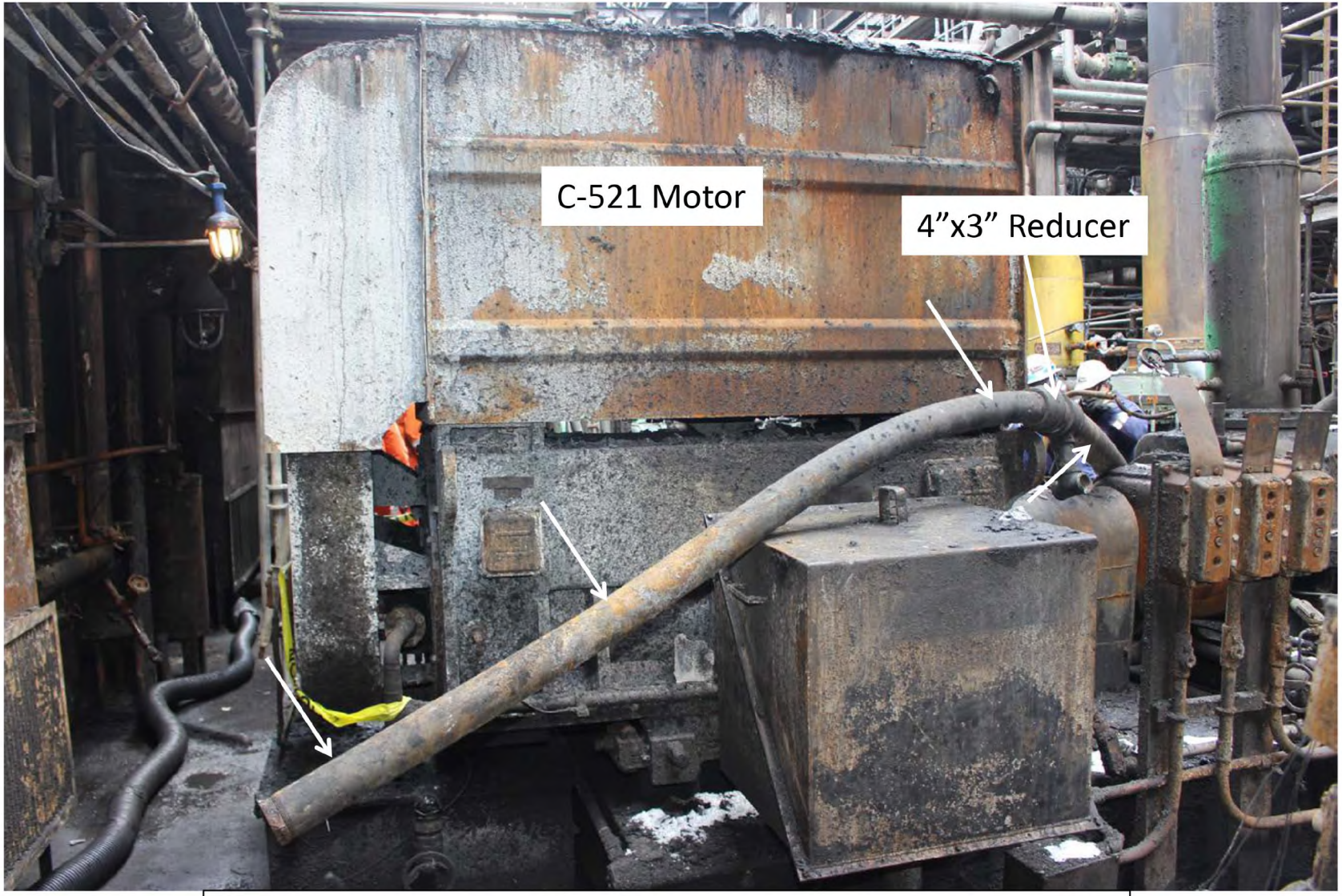


Photograph 6 - Pipe Section "C" – USS Research

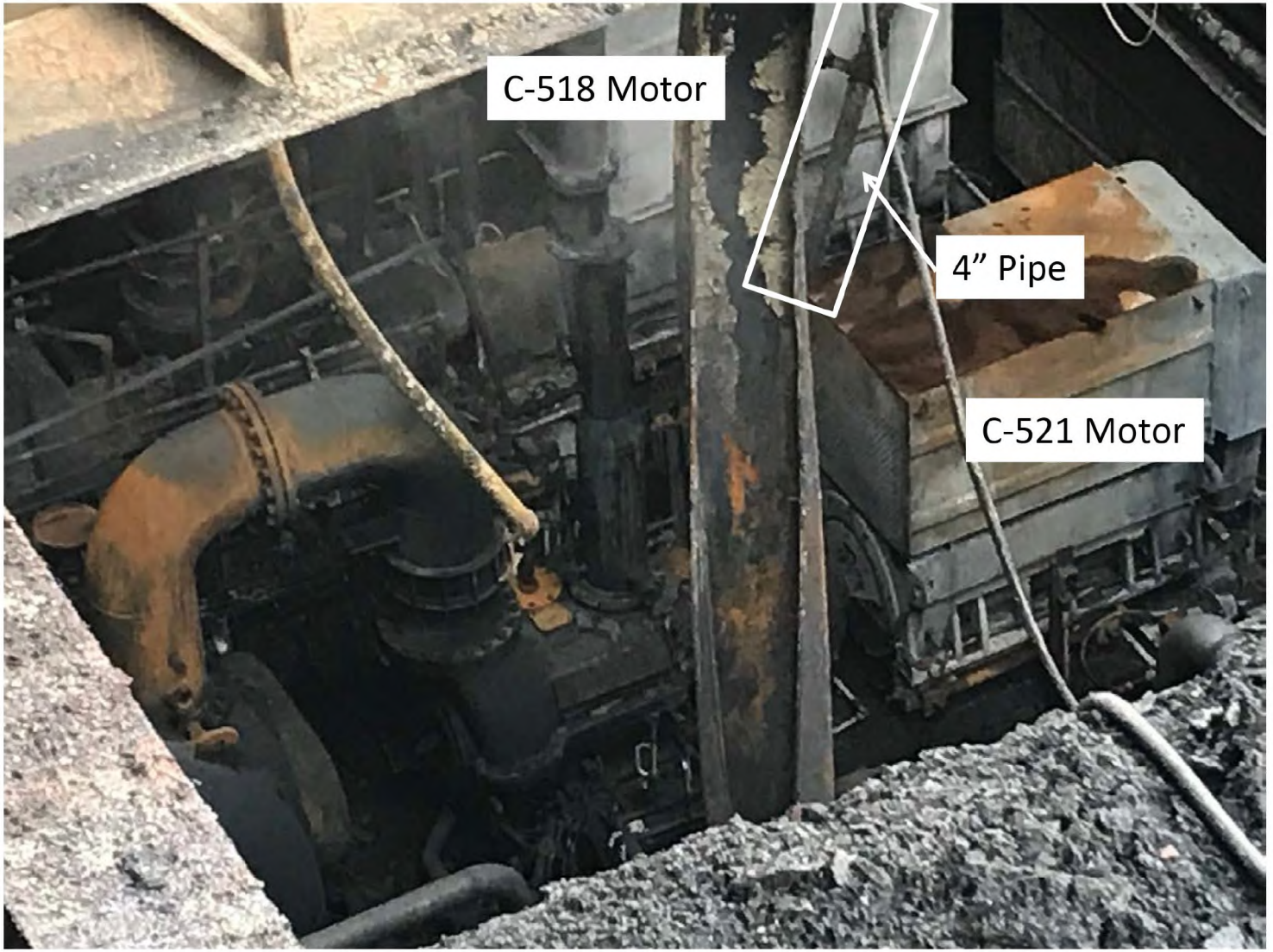
Photograph 7 - Pipe Section “D” – At C-524



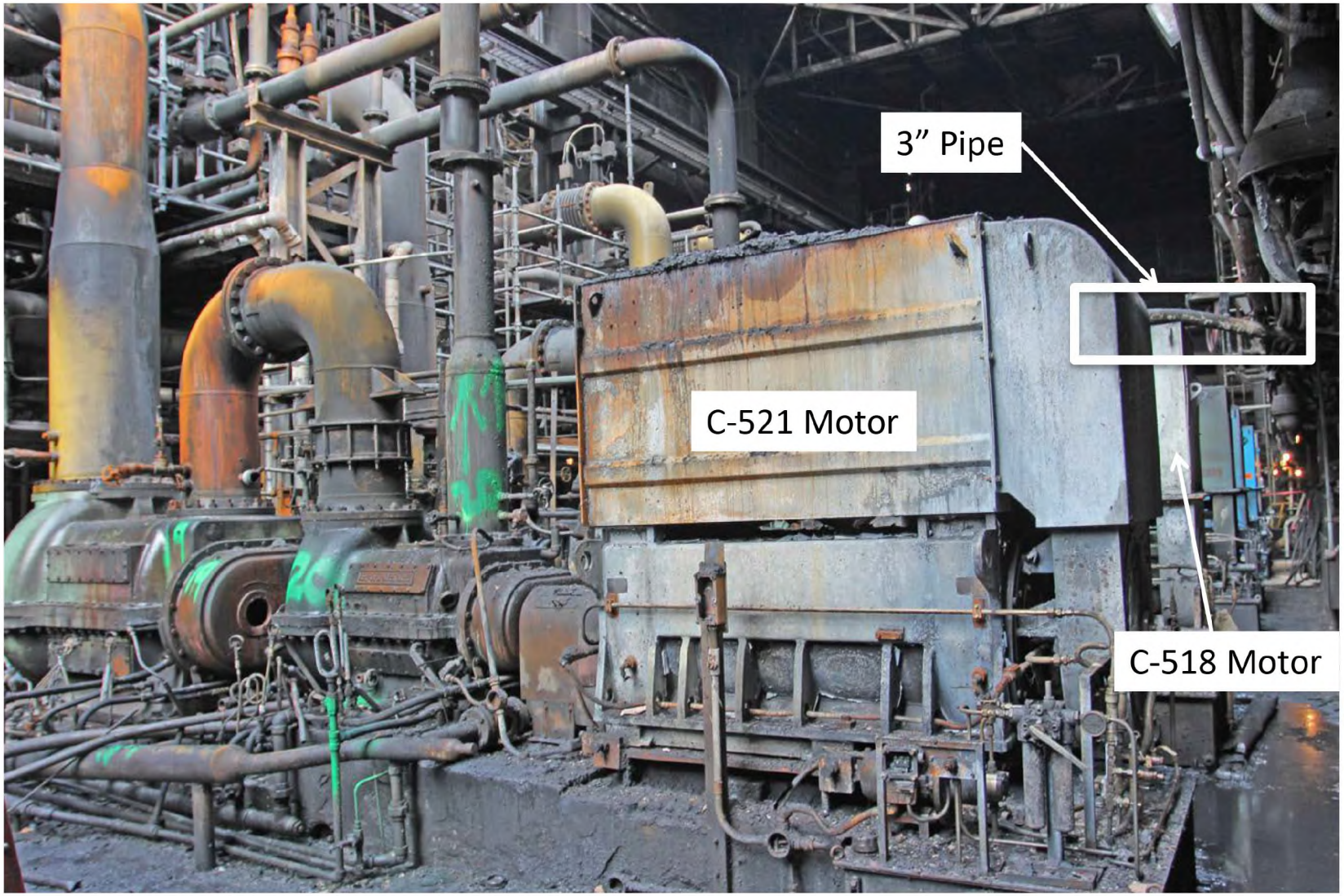
Photograph 8 - Pipe Section “E” – Relocated at C-521 Motor



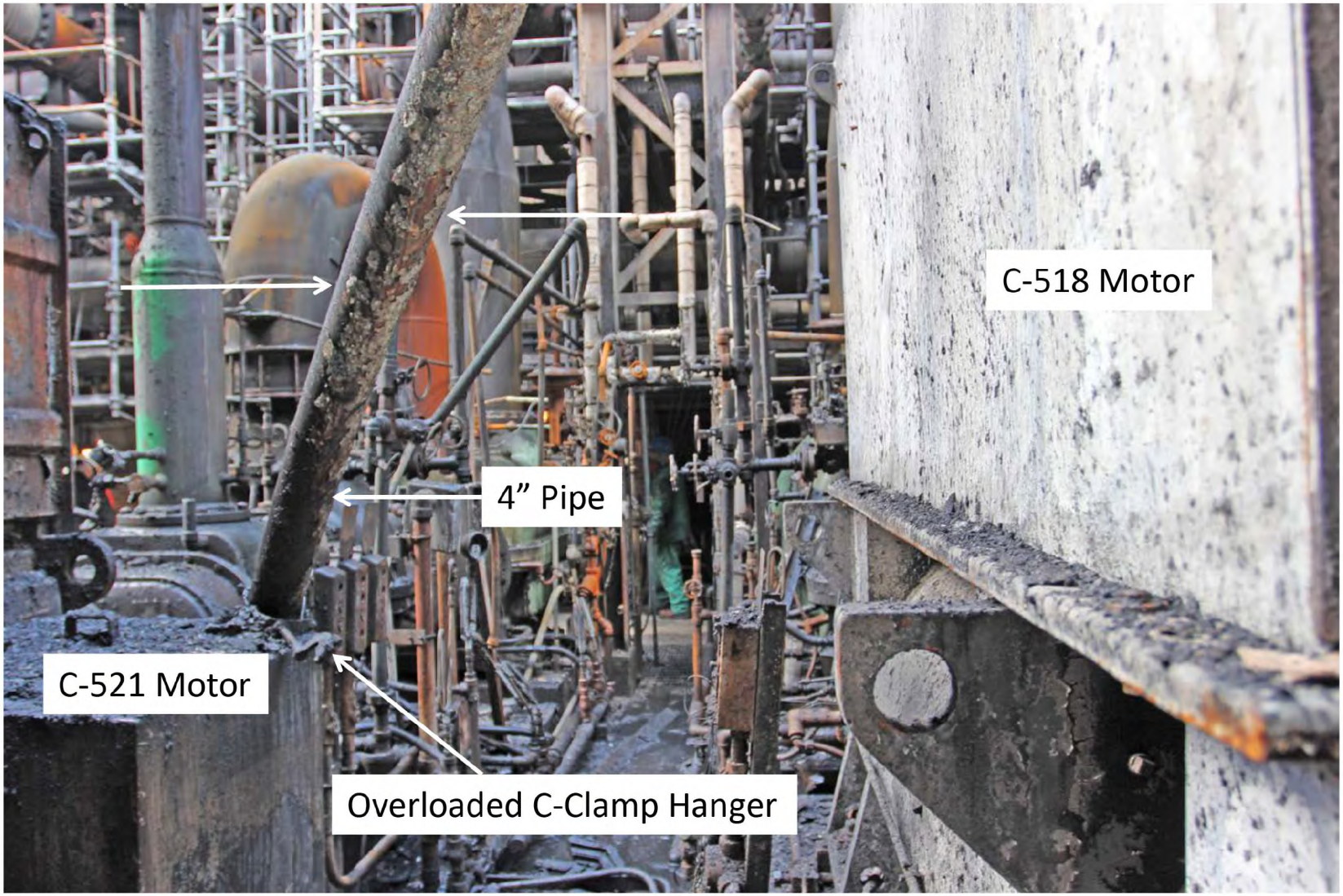
Photograph 9 - Pipe Section “E” – Relocated at C-521 Motor



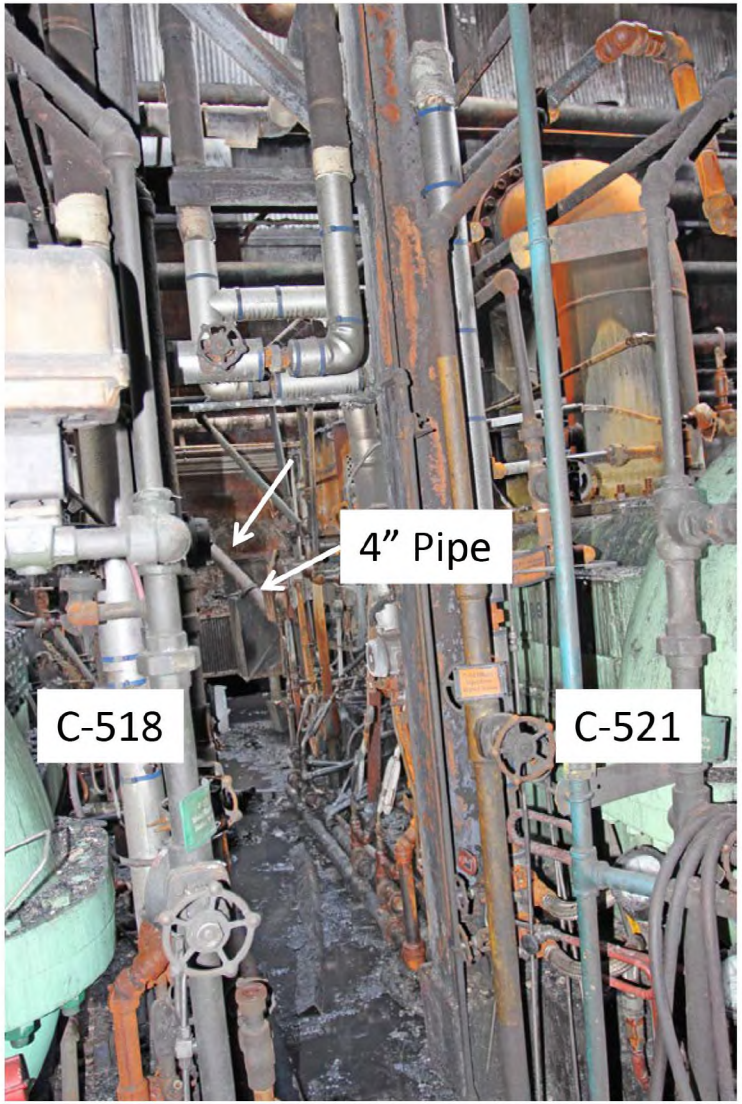
Photograph 10 - Pipe Section “E” – Post Incident (between C-521 & C-518 Motors)



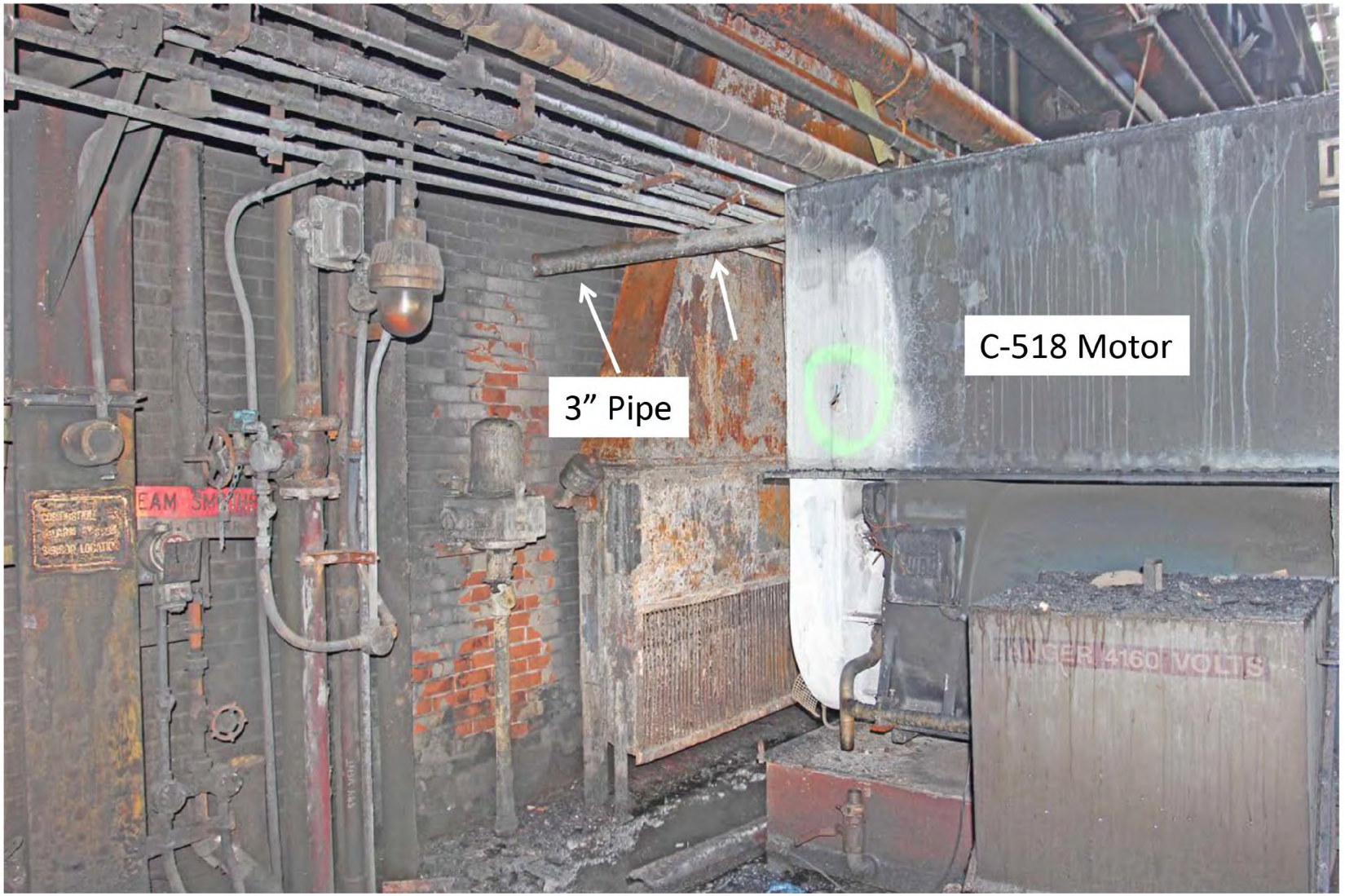
Photograph 11 - Pipe Section “E” – Post Incident (between C-521 & C-518 Motors)



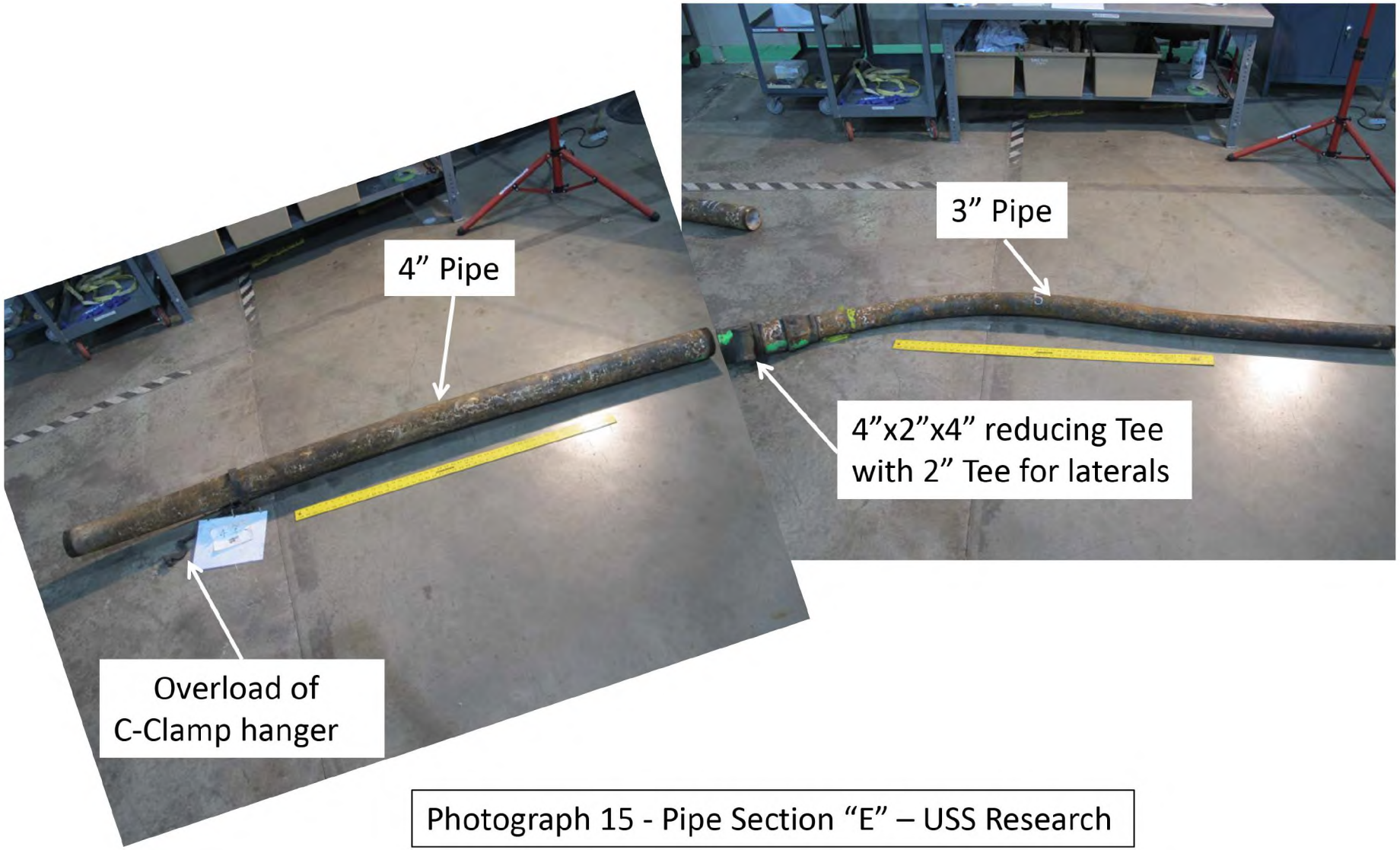
Photograph 12 - Pipe Section “E” – Post Incident (between C-521 & C-518 Motor)



Photograph 13 - Pipe Section “E” – Post Incident (between C-521 & C-518 Motors)



Photograph 14 - Pipe Section “E” – Post Incident (viewed at C-518 Motor)



Photograph 15 - Pipe Section “E” – USS Research

Photograph 16 – 4”x2”x4” Reducing Tee

Photograph 17 - 4”x2”x4” Reducing Tee