Journal of Chemical and Natural Resources Engineering, Special Edition: 80-89

WATER JETTING IMPACT ON NATURAL GAS PIPELINE

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ABSTRACT

Leakage of water utility piping system will create an orifice like situation to the water which is leaked from the water piping. When this happens it will create a phenomenon that called as water jetting. The present research concern the erosion effect of water jetting on NPS 8 carbon steel pipe. The 5mm diameter orifice was used as a source of jetting in sand particles that was jetted towards the pipe specimen. It is found that the thickness of the pipe decreases with time. The existence of tunneling effect was established through physical examination of the impacted surface. Determination of time taken for the pipe to rupture was established at 220 hours after continuous jetting. At 45 cm separation distance the pipe was totally uneffected by the erosive water jet.

Key Words: Water jet, erosion effect, pipeline, erosion, slurry erosion, natural gas pipe

1.0 INTRODUCTION

Problem of erosion has long been an issue in the engineering world. Work on erosion by liquid impact has been studied by various body especially one related to the mechanical engineering field[1,2]. Liquid impact upon mechanical equipments or metals can be seen in forms of cavitations or metal degradation due to erosion. Among pioneer problems that resulted to this study is the fact that buried natural gas piping are always under the threat of damage due to water jetting in cases where water utility piping which runs parallel to it got leaked. Degradation of piping material not only disrupts the continuous supply of natural gas it too could pose a threat to life and buildings in terms of lost of lives and destruction of buildings. Cases of natural gas piping failure has been proven to be catastrophic as demonstrated in cases of pipe rupture in South Riding, Virginia in 1998 and Carlsbad, New Mexico in 2000 [3,4].

Erosion at high speed impact of greater than 700 feet per second can never be contributed by chemical action [5]. Therefore, when chemical action was eliminated the only possible causes that can be contributed to erosion of the blades are erosion due to mechanical action of the liquid impact during its operation. However a jet's ability to incur enough damage in terms of thinning of the impacted surface highly depends on the force of the impact. Force of an impact will vary with the distance away from the jetting source as every jet will have its own effective jet length [5]. In short, a jet which is not in its effective distance will produced damages that is less than the damages caused by a well formed jet at the same velocity. This can be explained by the area of the leading edge of the jet. An irregular shape for a jet's leading edge will not be able to produce an impact area which is as large as the one in its effective distance due to the area behind the leading

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edge has a reduced velocity compared to the leading edge. This happens as a result of momentum lost as the length traveled by the jet increased.

Most unique characteristic that can be seen after a material has been deformed due to liquid impact is that it creates a ring deformation. The main feature of the deformation is a ring crack separating a region of intense circumferential fracture from a central unfractured area of the surface [6]. Central unfractured area of the surface happens due to the displacing properties of the liquid impact. During the leading edge impact on the surface pressure generated by the impact velocity results to the exertion of enough force onto the surface to exceed the materials shear strength. The force will be displacing particles on the surface continuously and uniformly thus creating the central unfractured area.

Particles being displaced from the central unfractured area will be force to move upwards towards the opening created by the liquid impact. This movement at high velocity resulted to the outer ring damages through shearing or tearing of the material surface. For the particles from the central area to move upwards it has to be at a velocity which is higher than the impact velocity. In short, the outer ring was damaged due to the radial force which is grater compared to the impact force due to increase of outward flow velocity [6].

Ductile materials refer to material which undergoes erosion process in the form of plastic deformation. Volume removal is normally due to the cutting or the displacing action of the solid particle in the liquid jet. Firstly it is to be expected that impact perpendicular to the surface would produce indentations but little volume removal in ductile material. However it is hardly the same for in cases where impact directions making a lower angle with the impacted surface due to the grooves which will be cut off the surface after the impact. Although it is true that little volume is removed when the impact is perpendicular to the impacted surface, one must not forget small cuts resulted from the impact can be aggravated when there are multiple impact as in the real situation of liquid jet.

In brittle material an entirely different result will be seen after an abrasive liquid jet impact. This is due to the fact that in brittle material erosion does not happen by means of plastic deformation but it is more likely related to the material's elastic behavior. Elastic stress of the impacting particles will contribute to the displacing action of the particle through propagation and intersection of cracks ahead of the impacting particles. It is found through a test that brittle material erodes most rapidly at angles near to 90 degree [7]. The explanation for this is that in brittle material angle of 90 degree for the impacting particle with the impacted surface allows a maximum component of velocity tangential to the surface with regard to angular particle. This maximum tangential velocity will be able to exert enough force to firstly propagate cracking of the impacted surface.

The present study will examine the erosive effect of NPS 8 carbon steel pipe. The discussion will emphasized on the erosion effect, thinning rate through the usage of 5 mm diameter orifice as a jetting source of 10 bar water jet pressure at fixed distance of 300 mm. Optical microscopy and digital ultrasonic thickness gauge were performed to characterize the pipe material and established the erosion rate of the tested pipeline.

2.0 EXPERIMENTAL DETAILS

2.1 Pipe Arrangement

A tank was used to simulate a buried piping system. A sec[illegible] was buried in the compartment to symbolise a working buried natural gas p[illegible] without gravels were filled into the tank thus burying the pipe. This sand [illegible] erosive particles to be present in the water jet to sand slurry situation. W[illegible] was created in the compartment by using different sizes of orifice poi[illegible] the buried pipe. Figure 1 is a diagram depicting the basic idea of the experi[illegible]

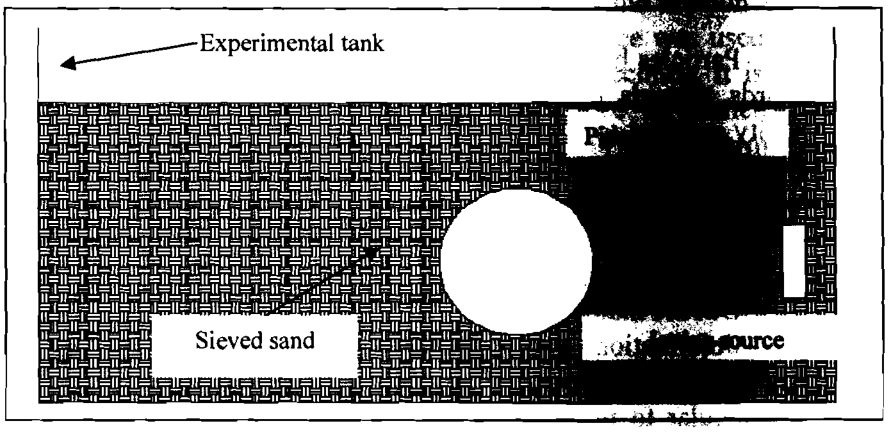

Figure 1. Basic concept of experimental apparatus

2.2 Pipe's Surface Preparation

The thickness of the coating and thickness of the pipe without the coating was measured by thickness measuring equipment. All the data for the coating thickness and the thickness of the pipe without the coating were recorded. Several sets of measurement data for every specimen were taken in order to get an accurate and minimum error in reading.

The surface of the specimen pipe was divided into 4 horizontal sections with 5 horizontal lines, namely Line A, Line B, Line C, Line D and Line E. The horizontal lines were separated into 3 areas with the data taking points being the center of the area. Coating thickness data on each area were acquired using digital coating thickness gauge. In order to determine metal thickness of each specimen a section of the specimen were scraped off its coating to reveal the bare metal surface of the specimen. Three data measurement were taken from the designated point as shown in Figure 2.

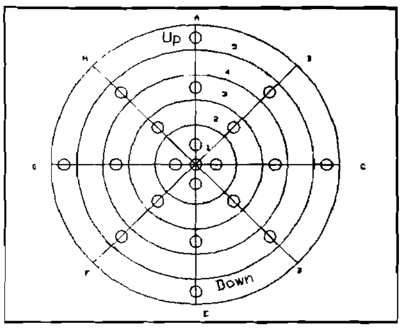

Figure 2 Data taking template

After all the procedures have been followed correctly, the specimen was tied to the pipe holder rig. Then, the position of the specimen is needs to be set in order to make sure the jetting of the orifice is parallel to the line and points that have been selected the surface of the pipe.

2.3 Experimental Rig

A section of natural gas pipe (NPS 8) will be attached to the saddle on the rig. The saddle was adjusted to a distance deemed suitable for the experiment. An orifice was attached to the orifice holder. Supply pressure of the water was set at 10barg while the distance away from the jetting source was varied at 10cm till 70cm. Sand that has been sieved to be at 600-2000micronmeters was filled into the handling tank before the rig was lowered into the tank. A number of small holes drilled on the rig structure will act as a creator of water jet which will be used to disperse sand in the tank to allow the rig to be lowered into the sand thus burying it. After the designated interval the rig was transported out from the handling tank using a chain block. Thinning of the sample pipe material was measured on points dictated based on a data taking template. Below is a schematic diagram depicting the experimental rig used in the study.

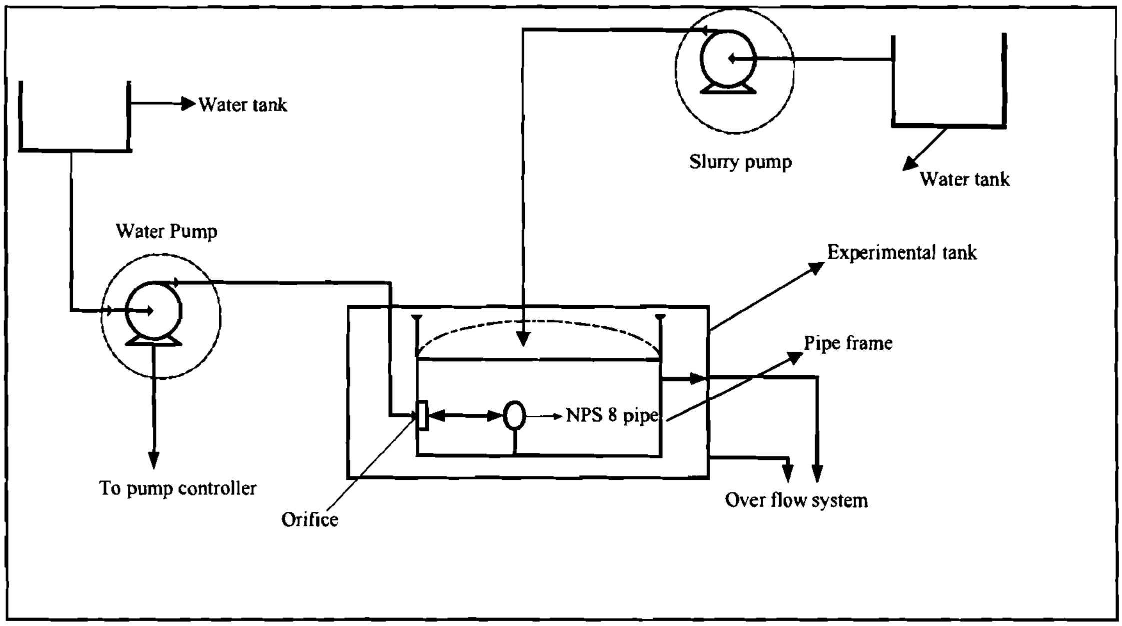

Figure 3 Experimental set up

2.4 Determination of Abrasion Effect

Abrasion effect was determined through visual inspection of the impacted surface after the end of testing which coincides which the identification of rupture point on the specimen surface. Besides visual inspection, physical examination too was administered through the act of touching the impacted surface with bare hands to determine the surface roughness.

2.5 Determination of Metal Thinning

Metal thinning effect was monitored through specimen thickness measurement after a period of jetting exposure. Thickness measurement gauges used in the experiment was of two types. Digital coating thickness gauge was used to measure the thickness of the pipe's coating. While the thickness of the bare pipe was measured using digital ultrasonic thickness gauge.

3.0 RESULTS AND DISCUSSION

3.1 Visual Analysis of the Impacted Surface

Physical examination of the impacted surface revealed that orifice jetting produces an impact on the specimen pipe which resembles a round shape. One thing peculiar about the impacted surface is that the roughness of the impacted surface is not evenly scattered with one being smooth while the other being very rough. Figure 4 below depicts a specimen surface after an exposure of 170 hours to arosive jetting.

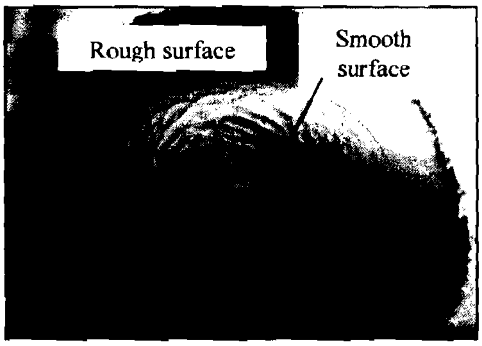

Figure 4 Specimen surface after impact

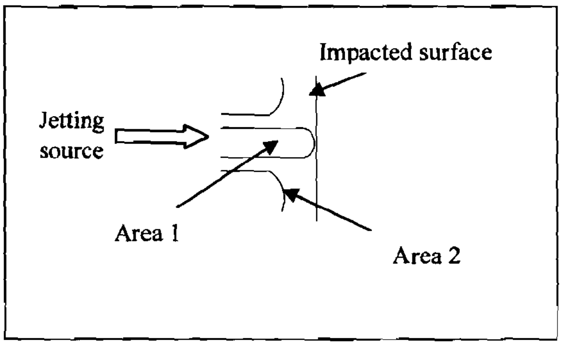

Figure 5 Orifice jetting profiling

The surface which experiences water as the main erosion media has a smoother section when compared to the surface which mainly experiences sand as the main erosion media. Area 1 is the one that has water as the majority erosion media. This gives an indication of the velocity of that area being higher compared to the velocity of Area 2 (Figure 5) which is normal in cases of orifice jetting where pressure at the jet's centerline is higher compared to the edge of the jet structure [8]. For example, velocity of the orifice outlet in Area 1 is a lot higher compared to the one in Area 2. Therefore its ability to carry sand particles is lesser due to the weight of the sand which reduces the sand particles' ability to move with high velocity as in Area 1.

3.2 Jetting Dispersion

Dispersion of water jet structure away from its center point is basically due to the high resistance of the initial impacted media which in this case is water impacting on sand particles. This failure resulted to the jet not being able to go further forward towards the specimen thus dispersing upwards or downwards according to its location away from its center point where the resistance is less due to the turbulence flow in the impacted media [9, 10]. The turbulent flow is a result of the jetting pushing aside the impacted media away from obstructing it from moving forward.

3.3 Proof of Tunneling Effect During Impact

Tunneling effect could be describe as a pathway created due to the dispersion of sand to give way for water jet which has a high velocity. During the experiment two types of tunneling effect was identified. First being the horizontal tunneling and vertical tunneling being the later.

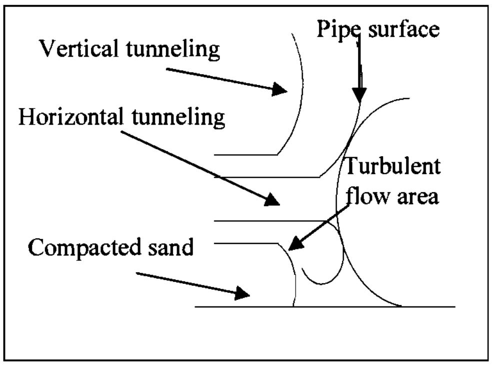

Figure 6 Tunneling profiling

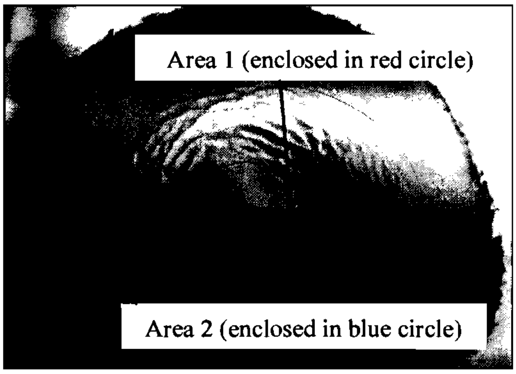

Figure 7 Tunneling effect on pipe

The above figures (Figure 6 and Figure 7) show that the existence of the vertical tunneling is due upwards movement of the jet after it has been impacted upon the pipe surface. Following the pipe curvature the upwards flow is a lot evident compared to the downward flow because compacted sand resistance on the upper side of the pipe is a lot lower compared to the one beneath it. Compacted sand above the pipe can be easily dispersed due to the condition above the pipe being in the manner of an open system which has direct contact with the atmosphere. Upward movement of the jet resulted to the gradual collapsing of the sand structure above the pipe specimen. This in time will bring upon a hollow like vertical tunnel which allows the movement upwards steadily without much resistance.

Horizontal tunneling existence can be explained by observing the nature of sand dispersion. When water is jet out of an orifice, it will push aside sand particles near the outlet of the orifice. Due to its high velocity, the water jet will act like a solid thus providing enough force to push away sand particles from blocking its way. Proof of the mixing of sand particles with the water jet can be seen through the identification of the rough surface upon the impacted surface and this is especially true as there are two different areas on the impacted surface (Figure 7).

3.4 Relationship between Specimen Thickness and Time

Pipe thickness is seen to be decreasing with the increment of time. Both physical examination and the graphs that were plotted it could be postulated that the rate of thinning in zone 1is a lot higher compared to the rest of the lines regardless of the lines on which the points are situated. The explanation for this occurrence is that the centre point of impact coincides with area 1 (Figure 7) which has water as the major erosion media as explained, thus hampering its thinning rate compared to the points in zone 1 which coincides with area 2 (Figure 7) of the tunneling created. Figure 8 and Figure 9 are the graphs presenting the relationship between thinning rate and time for line A and Line E according to data taking template as in Figure 2.

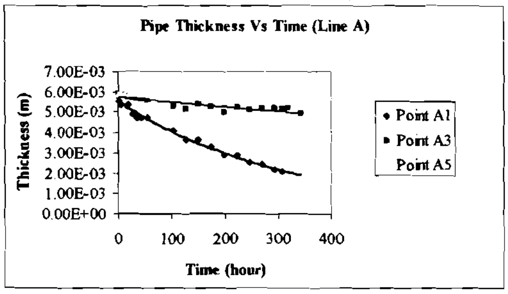

Figure 8 Analysis of line A

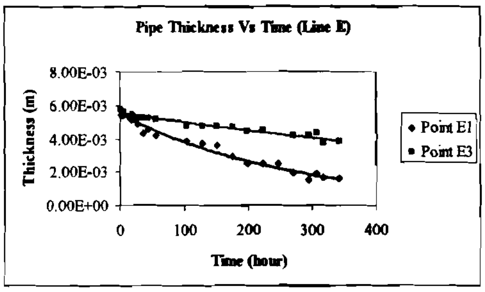

Figure 9 Analysis of line E

3.5 Dispersion of Specimen Thinning Effect

Table 1shows that the highest thinning rate is in the Line E region while the lowest thinning rate is evident in the Line A region. This could be explained by the existence of vertical tunneling near line A region and turbulent flow area near line E region as shown in Figure 9.

Table 1 Average thinning rate of orifice jetting

Point	Average thinning
A1	1.08X10-5
A3	2.87X10-6
A5	1.01X10-6
B2	6.84X10-6
B4	1.60x10-6
C1	1.10X10-5
C3	4.46X10-6
C5	1.41X10-6
D2	1.23X10-5
D4	3.28X10-6
E1	1.21X10-5
E3	5.73X10-6

The vertical tunneling allows minimum contact between abrasive media with surface in Line A region. The explanation for this is that the mass of the sand particles is way too high for it to move upwards following the vertical tunneling. While in Line E area movement downwards is being resisted by the compacted sand beneath the pipe specimen. Resulting from this is the circular flow of abrasive material in the water jet nearing Line E region as the water jet's flow is being resisted by the compacted sand beneath the pipe specimen.

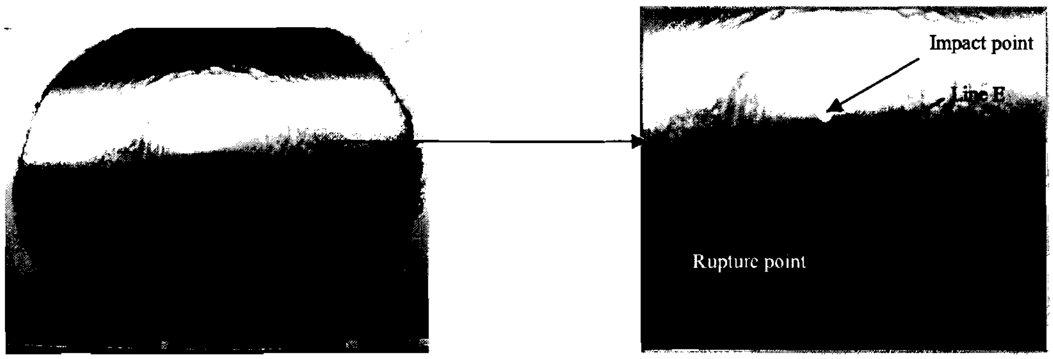

Figure 9 Picture of ruptured specimen

Besides the effect of turbulent flow in Line E region too is affected by the gravitational force where the sand with high mass will never be able to travel upwards without being pulled downwards by the gravitational force thus it will stays near Line E region which is a lot easier for it to comprehend rather than moving upwards which requires higher acceleration thus creating a higher concentration of abrasive material in that area. The obvious proof that Line E region has a higher thinning rate is the fact that the rupture point during the experiment was on Line E as shown in Figure 10.

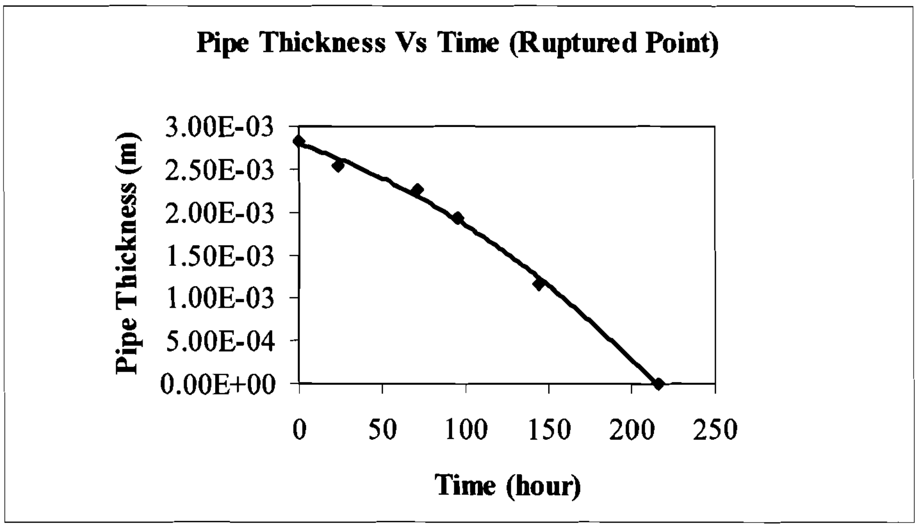

Figure 10 Thickness loss versus time for rupture point

From the earlier observation discussed, it is true that the area with the thinning rate or the rupture point coincides with Line E region due to the turbulent area present in that area. The rupture took place after almost 220 hours and this relatively longer compared to the real condition as an operating gas piping will have two types' forces acting against that pipe surface. First, being the one from the water jet impacting a the outer layer of the piping and the later being the force acting against the inner surface of the pipe due to the operating pressure of the gas present in the pipe itself either its within gas transmission or gas distribution system[7.8].

3.6 Zero Effect for 5 mm Orifice Jetting in Water to Sand System

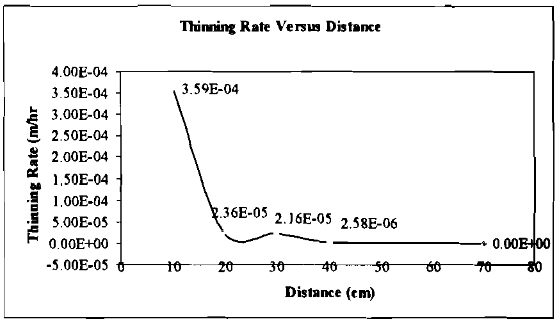

Figure 11 Thinning rate versus distance

A graph of thinning rate versus distance was used to identifify safe separation distance to placed the natural gas pipe adjacent to the possible leaked water pipe. Figure 11 shows that the erosive effect of the jetting stops completely at distance of 70cm away from the jetting source. According to the trend of the graph the distance that the abrasive effect upon the impacted surface stops starts at around the distance of 45cm away from the jetting source.

4.0 CONCLUSION

Erosion effect of water jettimg in sand toward natural gas pipe were envstigated. Erosion effect does contribute to the erosion rate of natural gas piping in terms of metal thinning. An increase in exposure time resulted to the decrease of specimen thickness. The existence of two distinct patterns on the impacted surface shows the effect of abrasive material dispersion is closely related to the velocity of the jet in its centerline region and region further away from its centerline. Pattern of impact and the dispersion of metal thinning showed the existence of vertical and horizontal tunneling due to velocity differences and gravitational effect. The pipe will ruptured after 220 hour of exposure time to the water jetting while at 45cm separation distance there will be no erosion effect on pipe.

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