ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 9, March 2014

Effect of Vehicular Movement on Petroleum Pipelines at Road Crossing and Cathodic Protection

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Abstract*- The trend of crossing in a busy road or highway with a carrier pipe is to provide a higher diameter metallic casing as per API 1102 or National standard. The basic purpose of providing a casing is to relieve the carrier pipe from external load due to traffic/ vehicular movement but the problems of cathodic protection to the carrier pipe and detrimental effect of corrosion within the casing have not been given due importance . The present paper is concerned with reliability of underground pipelines at road crossing when heavy loaded truck, trailer etc frequently move over the pipeline ROW and cyclic load is applied on pipelines and also gives the suggestive solutions to overcome this problem particularly for old pipelines.

***Index Terms*–Cathodic Protection (CP),Pipe to Soil Potential (PSP)**

I. INTRODUCTION

In India, cross country pipelines are the safest and most efficient means of transporting crude oil to refineries, processing plants and petroleum product to the consumer. The pipeline varies in size from 8" to 36" in diameter and was constructed in the 1970's or later. Many companies operate underground pipeline in India now a days. First cross country pipeline was commissioned in 1962 in eastern India. River crossing, rail crossing, road crossing is the common phenomena in cross country pipeline. The present paper is concerned with reliability of underground pipelines at road crossing (cased/ uncased) where cyclic external load is applied due to traffic movement over the right of way (ROW) of pipeline and its consequences on pipeline is corrosion either externally or internally or both resulting in puncture, joint failure etc. The design of underground pipelines is governed by different codes followed by different regulatory authorities. Based on material/liquid to be transported through the pipeline various codes have been developed internationally. We will try to examine what are the effects on buried pipeline at road crossing when heavy loaded truck, trailer etc frequently moves over the pipeline. Lets us find out the codes available for construction of cross country petroleum pipeline for road crossing. OISD-226 Minimum cover requirement for pipeline at cased/uncased road crossing is 1.2M IS-8062 "As far as possible, cased crossings should be avoided wherever they are not necessary. In India, it is mandatory to cross railway tracks by using casing. For pipelines crossing under rail / road tracks, etc, an agreement would have to be made with the concerned authorities. No long pipeline can avoid crossing of roads and rails. Special precautions are necessary at such locations to safeguard the carrier pipe by passing it through an additional oversize pipe termed a 'Casing Pipe'. The section of the pipe thus encased in the 'Casing pipe' is termed as a 'Carrier Pipe'. Casing pipes may act as a shield to the flow of cathodic protection current to the carrier pipes thereby defeating their primary purpose of providing safety." API 1102 Carrier pipe under highways should be installed with minimum cover, as measured from the top of the pipe to the top of the surface. Under highway surface, minimum cover is 1.2M; under all other surfaces with in right of way is 0.9M. Generally during construction, depth of pipeline at road crossing is maintained more than 1.5M. As per API RP 1102, for safe operation, the stresses affecting the pipeline at a road crossing must be accounted for, which includes both circumferential and longitudinal stresses. To avoid any mechanical damage of pipeline at existing road crossing it is also recommended to install casing. All kind of precautions are taken up during design stage of new pipeline at road crossing. Problems arise when pipeline becomes old. Due to rapid urbanization, expansion of existing roads, construction of new roads is a common phenomenon in developing country like India. Pipelines which have been laid 30 to 40 years back, are prone to damage either mechanically or due to localized corrosion at road crossing. Let us take a sample of pipeline of 40 years old. We will try to find out the effect on pipeline due to external load due to the traffic movement, corrosion and difficulties in cased crossing.

II. ROAD CROSSING WITHOUT CASING

In this case, pipeline at road crossings we have adopted a depth of cover of 1.2 meters minimum from the top of the pipe to the travelled surface of the road, in accordance with API RP 1102. The pipeline at road crossing will be subjected to both internal loads from pressurization and external loads from earth force (dead load) and traffic movement- Loaded truck, trailer etc (live load). In addition to the internal and the external pressures, the pipeline is subjected, in general, to corrosion, either externally or internally or both. Corrosion affects the pipe-wall thickness. It may be of a uniform in nature or severe localized to some extent. It is common practice to coat pipelines externally in an attempt to protect the pipe wall material from corrosion, but such attempts are not always completely effective. Road pressure impacts on coating's mechanical performance. The subject pipeline is buried under the road. Force exerted on buried pipeline a) Due to bottom soil b) dead load of soil and C) changing load delivered from the road surface, the gas or

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oil pipe made of steel is able to maintain a mechanical equilibrium.

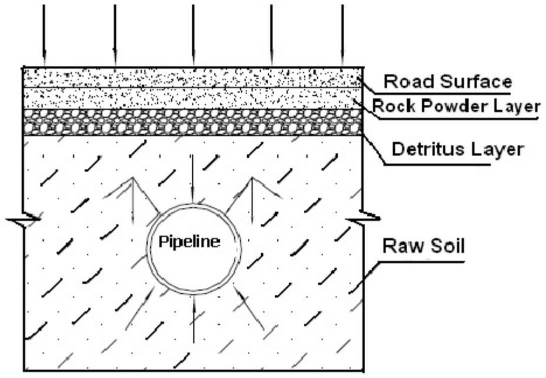

Fig. 1 Force diagram of buried pipeline

In case of a shallow burial depth where the total load on the pipe is not in equilibrium, the tensile stress generated due to differential load would then act on the coating materials and make the coatings mechanical performance of the upper pipe degraded more rapidly than that of the lower part. As a result coating on the upper portion of pipe will get brittle under the relative movements of soil particles. The electrochemical cell of "Small anode big cathode" will come into existence. When coating was broken, corrosion media in the soil would infiltrate through it from the breaking point, where later became the cathode of electrochemical cell, and the surface of the pipe became the anode. Since the area of the cathode is far larger than that of the anode, "small anode big cathode" situation is established so that macro scopical corrosion cell is constituted, which accelerates the corrosion rate where the coating's integrity has already been broken.

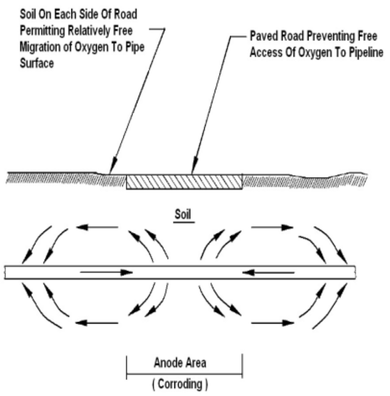

Fig. 2 Small anode big cathode

At road crossing oxygen concentration surroundings the pipe is lower because of traffic movement. This region of the pipeline becomes the anode in the differential corrosion cell. Current leaves the metal surface in this region, increasing the corrosion rate, and flows to the cathodic areas where the oxygen concentration is higher. Due to localized corrosion chances of corrosion leak at road crossing are more in comparison to the other area. More the depth of pipeline from the surface of road, less are the chances of localized corrosion. Buried pipeline without casing at road crossing are always at risk of failure due to overburden (the soil cover above the buried pipe) and cyclic traffic load. Buried medium and small diameter pipeline at road crossings and under access roads within plant or oil terminal boundaries or uncased road crossing that is not protected by any sort of casing, one of the root causes of piping failure at these road crossings may be the overburden (the soil cover above the buried pipe) and cyclic traffic load stresses that are increased on the carrier pipe because of local areas of reduced wall thickness (Which might have taken place because of local corrosion), mechanical damage such as a dent or surface cracking.

III. ROAD CROSSING WITH CASING

The trend of crossing in a busy road or highway with a carrier pipe is to provide a higher diameter metallic casing as per API RP 1102. The basic purpose of providing a casing is to relieve the carrier pipe from external load due traffic movement, to provide a path for leaky products to escape from road crossings and also to enable the leaky pipe to be replaced beneath the road surface. In general, highway authorities are in the favor of using casing and desire crossing to be made by trenchless technique only.

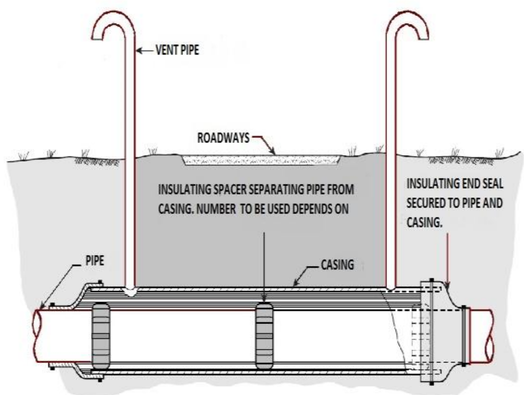

Fig.3 Pipe with casing at road crossing

The insulators are used to isolate the casing from carrier pipe electrically but in course of time these insulators tend to deteriorate in insulating property. Further, due to the compaction of soil during the construction stage and subsequent settlement of backfilled earth, the carrier pipe may go down and touching at the casing ends. This not only contributes to the increased local stresses but also causes shorting of the pipe with casing. The end seals too fail quite often and give way to water/slurry to enter inside the annulus within the casing. During construction stage, the external protective coating of the carrier pipe is likely to undergo damages while inserted within the casing. If the CP current does not reach the carrier within the casing, the bare surfaces at the holidays would be subjected to

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corrosion. In due course, leakage may occur inside the casing. The Metallic short may be created due to backfill of earth over pipe followed by compaction of soil and also due to the movement of carrier pipe because of variation of temperature and vehicular load. The electrolyte inside the annulus allows the carrier to receive cathodic current through the casing and carrier pipe become cathodically protected.

IV. STUDY OF CORROSION AT CASED ROAD CROSSING

A cross country pipeline of 530.14 kms with size 12.75 inch OD and 0.25 inch wall thickness and pipe grade is API 5LX 46. This pipeline was commissioned in the year 1967. No. of metal road crossing was 131.Pipeline is cathodically protected since commissioning.CTE coating has been used for the primary means of protection for pipeline.

Case: I

Pipe to soil potential and casing to soil potential was measured with respect to Cu/CuSo4 reference electrode after connecting current interrupter.

	ON PSP	OFF PSP
Pipe to soil Potential of carrier pipe	-1.220V	-1.060V
Casing to soil potential	-0.460V	-0.455V

From the above, it is clear that the carrier pipe is cathodically protected and level of protection is very good because there is substantial change in carrier PSP between ON to OFF. There is minor change in casing PSP between ON to OFF and moisture inside the casing because pipeline is more than 40 years old. Hence casing is isolated from carrier pipe.

Case:II

	ON PSP	OFF PSP
Pipe to soil Potential of carrier pipe	-1.430V	-1.180V
Casing to soil potential	-1.020V	-0.940V

The above measurement indicates followings

1. Carrier pipe is well protected cathodically.

2. Casing Potential is high and it is more than - 0.80V and value of casing potential is changing with interrupter. Shorting is suspected.

Fig. 4 Condition of partial shorted casing after excavation

Remedial Measure to remove the shorting:

1. Dehydration with compressed air.
2. Change of end seal to avoid further ingress of ground water. But there was no improvement in reading. When there is no improvement in reading after dehydration and replacement of end seal, excavation was stated for the removal of casing. After excavation we have observed that slurry is available in the form of solid inside the casing. Finally casing was removed.

Fig 5.Casing Removal under progress

Fig. 6 Condition of casing of old pipeline

Case: III

	ON PSP	OFF PSP
Pipe to soil Potential of carrier pipe	-1.230V	-1.08V
Casing to soil potential	-1.210V	-1.06V

The above measurement indicates followings

1. Carrier pipe is well protected cathodically but casing potential is almost same as carrier potential.

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2. Casing Potential is high and casing potential is changing with interrupter. It is also observed from the readings that shifting of potential from OFF to ON is almost same for both carrier and casing.
3. Metallic short was suspected. After excavation it has been observed that casing is touching with carrier pipe.
This was a NH crossing, culvert was provided for the crossing during expansion of NH but casing remained. During removal of casing it was observed that most of the insulator was in damage condition and casing is touching with carrier pipe. Further there was full of slurry inside the casing.

Case: IV

Test-I	ON PSP	OFF PSP
Pipe to soil Potential of carrier pipe	-1.40V	-1.11V
Casing to soil potential	-1.03V	-0.96V

Test-II (with increased feeding ON PSP OFF PSP current)	ON PSP	OFF PSP
Pipe to soil Potential of carrier pipe	-2.04V	-1.06V
Casing to soil potential	-1.23V	-0.94V

This is a case where expansion of road has been carried 10 years back but length of casing remains same. Two tests were carried out. One with normal feeding current another is with enhanced feeding current. With the increase of feeding current, ON potential of carrier pipe has increased substantially but increase of casing potential is nominal compare to normal reading. It is important to note that OFF potential carrier and casing are remain same in both the test condition but increasing while it is ON.

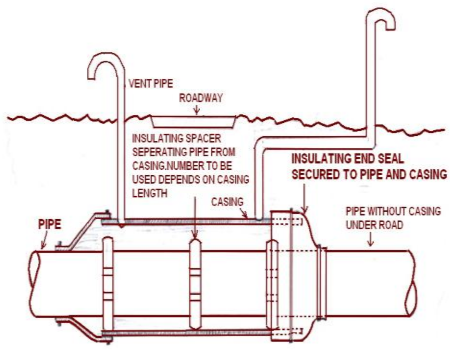

Fig. 7 Pipe with/without casing below road

Reading apparently shows, casing is partially shorted but condition here in this case is something different because carrier pipe under one lane is without casing and vent pipe extended up to end of road. Carrier pipe is coated with CTE coating and extended vent pipe also coated but conditions of coating is not known. It is quite possible that coating has been damaged for both carrier and extended vent pipe during construction or also due to vehicular movement. Due to damage of coating, current is drained from carrier pipe and same is being picked up by extended vent pipe. Further, due to continuous traffic movement, aeration of local soil may cause high casing potential. OFF potential of casing it self is high at this location. Change of casing potential with interrupter is nominal and this can be sorted out by dehydration with compressed air. Here in this case casing may not be shorted. Recently we have carried IPS survey in this section, no corrosion on carrier pipe either internal or external have been reported.

V. SUMMERY OF THE OBSERVATION

1. Chances of corrosion of buried pipeline without casing at road crossing is more because localized corrosion cell in comparison to other area of pipe. Further, Buried pipeline without casing at road crossing are always at risk of failure due to overburden (the soil cover above the buried pipe) and cyclic traffic load.
2. Partial shorting of casing of buried pipeline is common phenomenon at road/railway crossing particularly for old pipelines because of slurry inside the casing and failure of end seal.
3. An electrolytic couple occurs when a low-resistance electrolyte such as water or mud gets into the annular space between the casing and the carrier pipe, the pipe-to-electrolyte potential of the casing may shift with the application of current. If the casing is isolated the shift on the casing will not be as great as that of the pipeline and there will still be a potential difference between the pipe and the casing.
4. A casing may experience either a "metallic short" or an "electrolytic couple." A metallic short is a metal-to-metal contact between the casing and the carrier pipe. Such a short will usually cause an electropositive attenuation in the pipe to electrolyte potential in the area of the casing. If a metallic short exists, the structure potentials will be essentially the same from the pipe and the casing.

VI. RECOMMENDATION

Pipeline without casing if installed at recommended depth under a road or railway surface should not come under direct effect of mechanical (Vehicular) load. A casing as discussed above is a source of problem under all the circumstances and should be avoided wherever the road/railway controlling authorities allow the crossing by open cut method. To ensure a safe and longer life of the carrier pipe, following recommendations are suggested

1. The carrier pipe across the crossing should be of higher thickness to provide a corrosion allowances suitably.

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2. Horizontal directional drilling construction techniques at road crossing to reduce additional maintenance and monitoring of electrical isolation and the problems associated with electrical shorts, and loads on the cathodic protection (CP) systems.
3. In unavoidable situation, casing can be used as per standard but periodic maintenance and monitoring of electrical isolation is essential for safety of pipeline.
4. Application of good coating at cased crossing is essential.
5. Construction of new road shall be allowed across pipeline right of way only through culvert even if sufficient depth is maintained. It will help maintenance of pipeline in future.

VII. CONCLUSION

Casings are tending to become short with passage of time due to various reasons discussed above. From the safety point of view, it is always advisable to make the crossing without casing wherever possible. All the precautions and maintenance recommendations should be strictly complied with. The most important part is that the quality of the external coating applied to the carrier pipe at crossing to be ensured. If casing is provided across road/rail crossing proper monitoring and maintenance is a must to ensure the proper insulation between casing and carrier. Removal of shorted casing partially or fully shorted will help to maintain the effectiveness of cathodic protection system and life of the carrier pipe.

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AUTHORS BIOGRAPHY

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