Video Camera Inspection System

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Introduction

This project is an example of what can be accomplished when the various participating parties cooperate. Individuals that played important roles in the project came from Pearpoint (camera vendor), INDOT (Crawfordsville District and Research), Contractor (Fox Contracting), and Purdue University (Machine Shop and Civil Engineering). Jeff Tinlin with Pearpoint worked to provide a new camera head and the parts to fabricate the flexible extension. Steve Bray from the Crawfordsville District headed the fieldwork and worked on the 90° tee configuration problem. Gordon Hooker from Research participated in the fieldwork and in developing a solution for the 90° tee problem. Tom Williams from Research worked with Steve Bray to design and assemble the 90° solution. Jim Orr from Fox Contracting supplied the under-drain parts to create the 90° tee configuration in the lab. The Purdue Machine Shop produced the parts used to develop the 90° solutions.

Camera Selection

Based on the “Remote Camera Inspection System Synthesis Study” project, a camera vendor was identified, Pearpoint. Discussions with their area representative, Jeff Tinlin, identified a camera system that had the potential to be used in different pipe sizes and configurations. Using feedback from field experiences obtained on the previous project, Pearpoint developed a new camera head that has a more rigid and shorter fitting. The thinking is that a shorter flexible fitting should improve the ability to make the 90° joints.

The camera system consisted of a portable reel with 500’ of push cable, a display monitor mounted on top of the reel, and the camera head. This unit is shown below.

![Figure 1 - Reel, monitor and camera](image-url)
Under-drain Configurations

Over the years different configurations have been used by INDOT. Systems that were installed more than approximately three years ago are the 90° type. Since then INDOT has gone to two 45° joints to connect the lateral with the mainline drain. The more recent configurations provide for easier cleaning and inspecting with small diameter video cameras. Typically, outlet spacing has ranged from 200’ to 500’. The variation in spacing, pipe types, sizes, and configurations creates a challenge to find one camera system that fits all the requirements. That was the biggest challenge for the project.

The 90° tee configuration presented the biggest challenge for a camera system. The cable must be sufficiently stiff for pushing distances up to 400’ and flexible to make the 90° turn. Overcoming this proved to be a real challenge.

The camera system uses a shorter camera head and flex section. This is a new design for Pearpoint and it is made to reduce the length of the section that typically hangs at the tee. The camera in its original form was taken to the field and tested. The camera was pushed into several outlets and never could get past the tee. The cause for this could not be determined from the field trials. In order to determine the cause and test solutions a prototype under-drain system was built at INDOT Research.

![Figure 2 - Lab under-drain setup](image)

The above image shows a typical 90° configuration; a 4” smooth lateral pvc pipe connecting to a tee section that is connected to a 6” corrugated plastic pipe. A cutout was made in the top of the corrugated pipe at the tee, providing a view into the tee. When the camera was pushed in, the cutout revealed the problem.
The above image shows the camera head pointing down the mainline but due to the cable stiffness the cable/camera connector binds and is unable to pass the tee. The stiff push cable and the flex section work against each other at the tee. Developing a solution for this problem proved to be a challenge.

Steve Bray and Gordon Hooker developed and tested several implements to solve this problem. These are shown in the below picture.
Eight different devices were developed and tested in the lab. The only one that achieved any success is on the far left in figure 4. This is a metal bar that was fabricated in the Purdue Machine Shop. The bar is channel shaped, providing a place for the cable to lie. The bar is connected just below the flexible connection and camera head using mechanics wire and covered with duct tape. This option was tested in the lab and was successful. Results from field tests were good but exposed a few problems. One is the duct tape has a tendency to wear, exposing it, which provides surfaces that can stick to the inside pipe surfaces and create drag. Another problem is the direction is preset through the bending of the bar making it difficult to change directions at the tee. To do this the cable is rotated or turned. Removing the bar requires taking the tape and wire off and cleaning the cable. Also the cable can develop cuts and nicks at the two ends of the bar, which can deteriorate the cable. Because of these potential problems another option was developed and is shown below in Figure 5.

![Flexible extension for 90° tee](image)

The above was made from parts provided by Pearpoint. The cable is more flexible than the reel cable, allowing more bend through the tee providing a more shallow approach angle for the camera head which allows it to pass through the tee. The extension is screwed on to the end of the push cable where the camera head is normally attached and the camera head is screwed to the other end of the extension. This is shown in Figure 6. The extension is approximately 3 feet long.
One modification was made at the tail end. An additional 1-1/2 inches was added to the cable housing to provide more support and stability for the cable. This is shown in the below picture.
This option was lab and field-tested and proved to be successful every time. This experience and info has been relayed to the camera vendor and negotiations are underway for obtaining additional extensions. This solution allows INDOT to use the camera in the current existing under-drain configurations. The below image shows Steve Bray using the extension in the field.

**Figure 8 – Field test of flexible extension**

**Inspection**

Another important part of the study was to determine camera capabilities and inspection criteria for newly installed under-drains.

Different pipe sizes were inspected to determine the range of the camera. The limiting factor is the light source. This particular camera is equipped with a light head that provides 4 lumens. Another factor is the location of the camera inside the pipe. Normally the camera is pushed along the pipe bottom. In this position the light is focused along the bottom and the upper parts of the pipe are not illuminated very well. Moving the camera head up toward the center of the pipe provides a more even distribution of the light increasing the range of the camera. Gordon Hooker at research has developed several skids for this purpose. It raises the camera head toward the center of the pipe. He also has developed a skid with an additional light source further increasing the pipe size. Some skids are shown in Figure 9.
With no additional light source and pushing the head along the bottom, this particular camera has a range up to 18" diameter pipe. With a skid and additional light this range can be extended to approximately 30" diameter.

Another problem encountered during inspection of under-drains was double screens. Some systems have an additional screen at the juncture of the lateral and the main line pipe. So this screen occurs approximately 15-20 feet (lateral length) inside of the outside screen. This was done to prevent rodents from entering the mainline, however during inspection of some double screen systems rodents were found in the mainline (see the below image).
To inspect these systems the secondary screen has to be removed. Steve Bray developed a device that successfully removes these screens. It is made from chimney sweep sections, and has a hook on one end and a handle on the other end. The next two images show a secondary screen and the screen remover tool.

![Secondary screen](image1.png)

**Figure 11 - Secondary screen**

![Screen remover tool](image2.png)

**Figure 12 – Screen remover tool**

**Rubbilization**

During the inspection phase, the camera system was tested on various configurations. At one location interesting material was found inside the under-drain. On this particular section, the previous pavement had been rubbilized and when water percolated through the rubbilized material a slurry type substance forms in the under-drain. To determine the long-range impact on under-drains various age systems were inspected where rubbilization had occurred. Ages were 6 months, 1 year, and 10 years. The 6-month and one year old sections contained a considerable amount of the slurry mixture. This can be expected because one can assume the fine particles will be transported into the under-drains initially. After this initial phase, the slurry material should disappear. Inspecting the 10 year old section revealed continued problems with the rubbilized effluent. This
particular roadway section has a two-screen system, one on the outside and one at the junction between the lateral and the mainline. Six outlets were checked and only two secondary screens could be removed. The screens could not be removed because they had become calcified in place. Effluent from the rubbilized material had built up on the screen causing it to be cemented in place. The two screens that were removed had buildup in the screen area and the camera could not pass through. So the mainline could not be viewed and therefore its condition is unknown. Based on these inspections it may be beneficial to power flush these under-drains after an initial time period of a couple years. This flushing will help to remove a majority of this slurry effluent. Below are images taken in these under-drains.

Figure 13 - Screen build-up of rubbilized material – One year old project

Figure 14 - Slurry material inside mainline – One year old project
Inspection requirements for new under-drains

Another important activity was to determine an inspection percentage that INDOT should use for inspecting newly installed under-drains. Currently existing is a supplemental specification that requires 10% of the under-drains to be inspected. Is 10% an adequate amount or should it be increased? And if other percentages are used what are the associated requirements for time and cost?

Three inspection percentages were tried and the results documented. The percentages were 100%, 50%, and 20%. One mile segments of I-74 in Fountain County were inspected at these percentages. This part of I-74 had been rehabilitated within the last two years. The under-drain configuration is 2 - 45° transitions into the mainline. The mainlines have dead ends and range in length from 350’ - 450’. A two person crew inspecting 100% of the drains in a mile segment on one side will take approximately 8 hours. This is at a reasonable pace with occasional stopping to record images. Pushing
and pulling up to 400 ft. per outlet is very labor intensive and when the breaks between setups are short the crew can tire easily. The 50% option took 4 hours and the 20% option took 2 hours. At 50%, the break times are little longer allowing for longer recovery time and the crew will not tire as easily. At 20% the crew should not have a problem with fatigue. For all three segments no problems were discovered in the underdrains.

On a typical Interstate project there are outlets along both outsides and one interior line. So at the percentages stated, 100% would require approximately 3 days to inspect one mile; at 50% it would be approximately 1-1/2 days; and at 20% one day. A previous research project, “Remote Camera Inspection System Synthesis Study”, reported that subcontractor pricing for this inspection will cost approximately $100/hour and that productivity rates are approximately 4000-5000’ a day. This productivity rate is close to the mile a day experienced in the field test. So using $100/hr. the approximate cost/mile for an interstate at these percentages are 100% - $2400, 50% - $1200, and 20% - $800.

Based on field tests it is recommended that 20% is the preferred inspection rate. The current supplemental requires 10%; should it be increased to 20%? The time and cost difference between the two will be small. By doubling the inspection footage, will it create more incentive for the contractor? Or just having the minimum inspection at 10% enough to create contractor incentive? This is an issue for debate. Regardless, the 20% or the 10% levels are recommended over the higher levels. The main reason is it requires inspection of a hidden system thereby creating an incentive for contractor performance.

At 10-20%, District personnel could perform inspection of newly installed under-drains. However, this inspection must be performed in a timely manner and personnel may not be available. For estimating contractor costs, the cost data above is a reasonable estimate.

One other road was inspected, SR 67 in Muncie. This is a new roadway section and one mile was inspected at 100%. It took approximately one day for one side and no problems were discovered. Some of the laterals are spaced at 500’. Pushing this distance reveals that the cable becomes very difficult to push after 400’. The cable starts snaking because of the resistance. Distances greater than 400’ is a limitation with this camera system.

**Implementation**

**Equipment**

The below image shows the main components of the camera system.
On the left side of the image is the main component consisting of a reel with 500’ of push cable, the monitor is mounted on the reel, and the camera head attaches to the end of the push cable. This unit costs approximately $15,000. To the right of the reel is the floppy disk recorder made by Sony. The video signal from the camera is feed to the recorder where the images are saved onto a floppy disk. Approximately 20 high quality images can be saved to a disk. Compared to videotapes this is a preferred method because the images are saved in digital form. In digital form the images are stored, located and retrieved more efficiently thus eliminating the cumbersome videotape libraries that accumulate.

To the right of the Sony device is the Surface locator. The camera head has a sonde device that emits a signal. The locator detects the signal and can determine the depth down to the signal. This is helpful if the camera encounters an obstruction, then the surface location is needed for maintenance reasons.

These three components comprise the main parts of the system. Their approximate costs are: reel, 500’ cable, and camera - $15,000; Sony floppy disk recorder - $500; Surface locator - $2000. One item not shown in the image is an inverter that is used as the power source and is charged off the vehicle battery. The three-foot extension piece previously described is a necessary item for 90°. Another item not shown is a goggle head set that an operator can wear to view the camera images. This provides more freedom and in bright sunlight the monitor screen can wash out making it difficult to see the image. With the headset the operator has an improved view. The goggle headset costs approximately $800. There are other miscellaneous items that are necessary and include the following.
Hardware for New Construction Inspection

1. 40' of 3/4' sturdy PVC pipe
2. Dowel rod to hold the PVC together with mechanics wire
3. 3/8" power drill with adjustable torque
4. 9/16" socket with wrench
5. Box of shop rags
6. Plumbers cleaner for lens and cable
7. (1) 10' of 3/4' conduit for handles
8. (1) 2" long sweep 90 degree angle- scoop
9. (1) 3" long sweep 90 degree angle- scoop
10. (1) 4" long sweep 90 degree angle- scoop
11. 2 gallon jug of water for cleaning cable assembly
12. 1 spray bottle for water or cleaner
13. 1 jar of hand cleaner

Hardware for Old Construction Inspection

1. (5) 4" sections of chimney sweep graphite rod with screw on ends
2. 1 steel hook or bent nail to use as secondary screen puller
3. Chimney brushes 2", 3", and 4" in dia.
4. 1-13 from list above

Safety Items

1. 3 or 4 safety vests
2. 3 or 4 pair of work gloves
3. 3 jobsite cones
4. first aid kit
5. warning flags

This project has produced a camera system that can inspect a range of pipe systems; from under-drains to drainage pipes. Enhancements developed through this project and at INDOT Research expand its capabilities described herein. The digital option is an inexpensive, easy way to record, store, and manage pipe image information. This equipment has been turned over to the Crawfordsville District and placed in the back of a 97 Chevy S-10 long-bed truck that had a topper cover installed. The topper cost $1255. An inverter was installed to power the equipment. The next two figures show the truck and the equipment.
Steve Bray of the Crawfordsville District designed and constructed the layout. The equipment shown here including an inverter and with supplies listed above will cost approximately $20,000. This setup provides the capability to inspect the under-drain systems and small diameter pipes.