FINAL REPORT

Emerging Bedding, Padding and Related Pipeline Construction Practices

To:

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Interstate Natural Gas Association of America

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Emerging Bedding, Padding, and Related Pipeline Construction Practices

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by

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Executive Summary

Increased demand for fuels and other hydrocarbons has depleted transmission pipeline supply basis near early markets, requiring longer pipelines to increasingly remote supply basins located typically in challenging geographic and climatic conditions. Shifting population centers and related markets such as distributed power generation have likewise driven this process. This has prompted evolution of new or emerging construction practices, as well as developments in thinner and stronger line pipe, and new coatings. Coupled with developments in construction equipment and practices to deal with these challenges, such improvements could add value through increased safety and reliability due to reduced extent and/or severity of construction related coating damage that necessitate repairs.

This project assessed enhancements in safety and productivity possible through recently developed construction practices, and identified and evaluated opportunities for cost reduction, improved pipe protection, and decreased construction created pipe/pipe coating damage that could be realized with new or emerging pipe support and padding/backfill practices. Data were gathered subject to the practical constraints imposed by use of construction equipment and the contractor's permission to enter or approach the ditch for "hands-on" measurements and close-up observation.

On-site measurements and observations made in reference to the five sites considered lead to the following general conclusions:

- The performance of bedding and padding machines is dictated by the properties of the soil and soil mechanics, in addition to design and operating features that might be unique to a given machine. Differences in performance characteristics between integral in-line loader and screen machines and independently loaded stacked vertical screen machines preclude a one-size-fits-all basis for machine selection.
- Coating damage resistance is a major factor in the viability of bedding and padding practices and specifications, as tough durable coatings were resistant to damage.
- The relative significance of bedding and padding practices designed to avoid damage is limited where adequately damage-resistant coatings were used. Performance-based specifications for coatings and construction practices appear viable in this context, with validation needed to make them widely accepted.
- Dynapad develops a layered backfill, grading and placing three tiers of fill material. But, whether this enhances integrity depends at least on the damage resistance of the coating.
- Where appropriate skill is practiced, an Ozzie (and likely other similar designs) can bed and pad without undue damage to pipeline coatings, at least for the coatings and trench conditions addressed in this project. Significant to this conclusion is the skill of the operator, the coating used, and the screen size involved.
- The KNI assertion the washout occurs due to horizontal or vertical trench instability is viable, but there is little practical field data to identify when or where it is an issue. Use of geotextile laid by Dynapad is unproven to stabilize vertical washout, and inconsistent with other somewhat proven applications to control washout using geotextile fabric.
- Analytical considerations indicate the complicated response of foam structures make it very difficult to achieve selectively control bench "failure" – as suggested for the KNI

patent-pending precast foam bench – given the locally variable conditions and loadings typical in most ditches.

- Some areas have been identified for future development, the focus of which is combination crusher/padding machines and the evolution of damage-resistant coatings.
- Some technology starved areas exist in regard to the aspects of pipeline construction considered, for which several recommendations are included in the report.
- Forums organized around topic such as ditch stability, new technology, and other topics noted in the report might be effective in defining the issues, if any.

A number of less general but still important conclusions follow from the measurements and observations made at the five sites considered. These are detailed in the summary and conclusions section of the report, and justified in the observations and trends developed based on the field observations and measurements.

Introduction

The gas and liquid pipeline infrastructure began to develop as these products were recognized as merchantable. While other forms of transportation existed, pipelines were eventually recognized as the safest and most economical means to move these products from supply basins to markets. Supply basins were initially located nearby markets, as early finds of these resources were located in Pennsylvania. As demand grew and the nearby resources began to deplete, wells went deeper and supply basins became increasingly remote. This scenario continues today, with current interest in moving domestic supplies from areas like Alaska to the lower forty-eight.

As the supply basins became increasingly remote, a system of pipelines developed to transport products to the various market centers. This has developed a cross-country infrastructure that runs throughout the US and connects with border countries. Early construction traversed the plain states, with limited construction into and through wet or swampy areas as well as hilly or mountainous areas where such features lay between the supply basin and the market.

Early construction made use of backhoes and various ditching practices, with the pipeline built along and lowered into the ditch as a string. As construction usually traversed farm fields, the ditch bottom was smooth and native soil could be returned to the ditch as cover for the pipeline. A-frames gave way to side-booms beginning in the 1930s, while machine-made bends replaced couplings other field-bending practices needed to change the direction of the pipeline beginning in the 1940s. As the threat of corrosion was recognized, over-the-ditch coating methods were developed, with such coatings widely used beginning in the 1940s[1].

Construction up and down hills or through rocky areas used practices similar to those used for construction across flat country, along with schemes developed or adapted to move or anchor up and down hills, protect the pipeline from rock damage, or screen native backfill for acceptable fill material, or use replacement fill materials. Techniques used to move or anchor in hilly or mountainous terrain evolved with the demands of the pipeline industry, adapting equipment typically developed for other off-road applications. Approaches to deal with rocky ditches and native backfill addressed the perceived threat to the pipeline. One early approach to deal with rocky ditches simply replaced backfill below and around the pipeline with select backfill that was free of material considered a threat to the pipeline. A related practice used sandbags stacked periodically below the pipeline to raise it off the ditch-bottom, which allowed select backfill to flow under the pipeline. Another early approach used wood cribbing around the pipeline as protection from rock damage. As these schemes relied on logical methods to avoid or limit rock and related damage, variations on these methods using modern materials and more streamlined practices evolved and some continue in use today.

Variations in technology that have continually evolved from the early practices are outlined in written histories associated with pipeline construction[(e.g., 2,3)*]. Likewise such variations can be found via Internet web searches. For example, the key words rock shield in relation to

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[1] For details on construction practices and the related aspects see Appendix G of Reference 1. A timeline for the introduction of developments associated with pipelines can be found in Appendix H of Reference 1.

* Numbers in superscript parenthesis refer to the list of references compiled at the end of this report.

transmission pipelines lead to several modern variations that rely on wraps involving several modern polymers deployed over a range of schemes[e.g., see 4-7]. Likewise, the key words bedding and padding tied to transmission pipelines lead to at least eight websites detailing a range of competitive equipment[8-15], each of which claims to be the best in one or more important aspects such as cost or effectiveness. The evolution of bedding and padding equipment can be seen in comparing Figure 1a, which shows a 1940s vintage padding machine[16], with Figures 1b and 1c, which show two of the more recent machines. Whereas existing, emerging, and new bedding and padding equipment largely rely on screening technology where flat screens are deployed in various ways, angles, and sizes, using one or more screens loaded by various schemes, the 1940s machine used a rotary screen. Because of this flat mode, the modern machines load via conveyers whereas the 1940s vintage machine used an auger.

The evolution of bedding and padding equipment can be tracked through feature sections in pipeline industry trade magazines that document such equipment, along with related trenching and other construction equipment. Such magazines and supplier websites also address coatings used by the pipeline industry to help limit corrosion along with the use of cathodic protection schemes. Early, thick and compliant bitumen/tar-based, over-the-ditch pipeline coatings seemed well suited to protecting pipelines from construction-related damage, although over time these have been replaced by typically much thinner coatings.

As time passed, demand increased for petroleum products, which motivated an increase in both pipeline diameter and line pipe grade. This led to increased throughput and decreased construction cost and time. But it also facilitated a decrease in wall thickness, which increased the diameter to thickness ratio that occasional led to denting where the pipeline sat on sandbags used in construction. This motivated the search for alternatives to the stiff support provided by sandbags used as standoffs from the ditch bottom during construction. As supply basins moved to more remote regions and population shifts moved markets, routings through more mountainous regions motivated alternative approaches to dealing with rocky terrain.

Developments in machined trenching that could cut through even hard rock provided a neatly formed well-defined ditch alternative to the earlier practice that shot a wide often ill-controlled trench. This alternative technology also developed an ample supply of rock fines that provides a viable backfill alternative to the large sharp rock shards that often resulted where rock was shot. Moreover, the well defined narrow ditch limited the amount of fill needed in contrast to an ill-formed shot ditch, and provided an otherwise undisturbed construction site, all of which provide cost advantages over historical practices. Problems with over-the-ditch coatings that disbonded over time because their volatile content evaporated motivated development of alternative coating methods. These new mill-applied fusion-bonded epoxy and mill or field applied tape-applied coatings reduced time on the spread and improved metal-loss protection, and reduced costs through reduced cathodic protection (CP) demand. However, while polymer-based thin film and tape-applied coatings have the advantage of being tough and resistant to tearing or disbonding, they might be prone to spalling or cutting under point contact. The industry has addressed possible backfill damage to such coatings, although the results tend to be viewed as commercial property[e.g., see 17], and such work continues[18]. Likewise, technology is evolving to determine the extent of construction-related coating damage[19].

Improvements in pipe making and coatings coupled with developments in bedding and padding practices for hard, rocky ground could add value through increased safety and reliability due to reduced extent and/or severity of construction related coating damage that necessitates repairs.

a) 1940s vintage CRC auger loaded cylindrical-screen machine

b) modern integral in-line flat single-screen padder (Ozzie 200)

c) modern independently loaded vertical multi-screen padder (KNI) (commercial backhoe (loader) and sideboom (transport) also shown)

Figure 1. Comparison between vintage and modern bedding and padding equipment.

And, given the occasional rocks are found in softer ground, it is reasonable to conclude such improvements could bring similar benefit for such scenarios to the extent that rock is present. Benefits may also accrue for spreads involving periodic runs of rocky soil or hard rock, which otherwise require imported material for bedding and padding, or use of equipment that crushes and/or screens native spoil as required. Such benefits would be maximized where the equipment is suitable for continuous use, with equal or greater rate of forward progress as compared to usual practices, as otherwise nonproductive periods and the cost of moving it along the spread would offset their potential value. Potential benefits also could be claimed when formulating integrity-management plans (IMPs) for pipelines running through high consequence areas (HCAs) where practices that produce enhanced safety and reliability through reduced extent and/or severity of construction related damage are used. Where this occurs, it will be useful for regulators to have a basis to evaluate the value of construction practices in reference to integrity. Reference 2 defines the requirements of such IMPs, and provides definitions or related regulatory guidance.

Objective

The stated objective of the Government project funded through the US Department of Transportation (DoT) Research and Special Projects Agency (RSPA) project was to assess the merits of modifications to construction equipment and practices to enhance safety and productivity achieved through use of recently developments. The stated objective of the cost-share for the RSPA project funded through the Interstate Natural Gas Association of America (INGAA) was to identify and evaluate opportunities for cost reduction, improved pipe protection, and decreased construction created pipe/pipe coating damage that could be realized with new or emerging pipe support and padding/backfill practices. Both projects had interests focused on specific developments by KNI in comparison to existing technology.

These objectives couple concern for safety and reliability of the as-constructed pipeline in balance with aspects related to productivity during construction. To be comprehensive, the extent to which safety and productivity are enhanced through recently developed pipe support and padding/backfill practices must be evaluated relative to existing practices, and do so for the range of ditching conditions where the benefits of such enhancements could be evident. Meeting this objective will provide a technically sound basis to determine which practice is optimal as a function of right-of-way specific issues, and it will establish a basis for determining the safety-related value of such practices.

Approach

Evaluating safety and reliability in balance with construction productivity requires field data that involve metrics that reflect safety and characterize productivity and possible cost reduction. This necessitates an empirical approach that uses field observations as the basis to gather data, which then are evaluated to meet the project's objectives.

Given the project's objectives involve productivity as well as safety and reliability, observations must be directed at opportunities to improve productivity, or reduce cost in balance with improved quality in operations associated with ditching and pipe-laying. Metrics of productivity are needed, along with metrics of safety and reliability. Field data consistent with the metrics

must then be gathered to characterize qualitative and/or quantitative measures of the extent to which current or emerging practices could be improved or new practices developed to enhance safety and value-based quality, in balance with reduced cost and enhanced productivity, for construction situations from hard rock through soft soil.

Definitions

The approach just outlined involves the empirical comparison of current and emerging or new practices and equipment in terms of productivity as well as safety and reliability. However, as yet the timeline for current versus emerging or new has not been defined, nor has productivity nor safety and reliability.

Consider first definition of a timeline to discriminate current versus new or emerging technology. The most relevant definition of timeline follows from the realization that each contractor makes use of known and thereafter proven practices and equipment. Practices and equipment become favored through an experience-based trial and error process, and thus reflect the portfolio of prior work and circumstances encountered by contractors along the rights-of-way they work. On this basis, practices and equipment that become favored reflect the equipment that is either owned or available for a given job, the circumstances known or anticipated along the rights-of-way, the negotiated value for extras, and a host of other parameters. It follows that construction practices and equipment that are considered "known or proven" are contractor-specific, and also specific to the anticipated circumstances along a given routing. Thus, what is new versus emerging versus existing reflects equipment or practices that might differ contractor to contractor, which for a given contractor might be routine and another neither known nor proven. On this basis, what is taken as new or emerging versus existing when generalized across the industry reflects equipment or practices that are neither known nor in widespread use across the industry.

For purposes of this project, the timeline for new or emerging is measured in reference to the introduction of technology that produces layered-backfill for purposes of bedding and padding. In reference to Figure 1, a major step in developing screening technology to separate select backfill came with the shift from a rotary screen to the use of a flat screen. As virtually all equipment now advertised for such purposes relies on flat screens deployed in various ways, a criterion other than screen orientation is needed to discriminate timeline and what constitutes emerging or new. One major feature that differs between the various screen-based machines that could be used to discriminate a timeline in planning these projects is the ability to create "layered backfill", which is graded from fine near the pipeline to increasingly coarser moving away from the pipeline. As the benefits of layered-backfill are central to the interests of both the INGAA Foundation and RSPA, this criterion was chosen to discriminate between new, emerging, and existing technology. In this context, layered-backfill as produced in the manner of Reference 10 is used to discriminate between widely used screening-based equipment. As layered backfill defines the timeline for "emerging" technology, while developments that enhance the process beyond layered backfill comprise "new" technology. It follows that flat screening-based technology that does not produce layered backfill comprises "current" bedding and padding technology, as would rock shield and such long-known protective schemes.

Consider now safety and reliability defined in terms that can be measured in the real-time under constraints typically associated with commercial pipeline construction. For present purposes these definitions are established in reference to pipeline integrity as perceived in IMPs[(e.g., 19-21)].

Safety and reliability in this context are defined in reference to "threats" to pipeline integrity, and the hierarchy of significance of these threats. Threats to integrity are typically assessed in reference to pipeline incident experience, which is tracked in the US on Office of Pipeline Safety (OPS) reporting forms that are specific to gas versus hazardous liquid service[22]. This experience is documented on the OPS website[23], and widely discussed in the literature[24,25].

While the hierarchy of significance of threats is specific to the pipeline's service, one can reasonably conclude that external corrosion and mechanical damage are universally important. Safety and reliability in this context involve initial coating quality and the absence of shape change caused by construction damage. Thus, for present purposes safety and reliability are defined specifically in reference to coating quality and the absence of line-pipe shape change caused by construction damage. Within this definition, construction equipment or practices that do not reduce as-applied coating quality is viable. Likewise, construction equipment or practices that do not cause a permanent change in pipeline shape is viable. As-produced coating quality and pipeline shape define the reference against which quality and shape are judged. Abnormalities introduced in construction involving coating quality and permanent change in line-pipe shape are defined in accordance with usual conventions and the API 5L specification[26]. Terms specific to this report that could require clarification include:

- Coating Anomaly – Any deviation in the properties of the coating found by inspection, such as jeeping or visual observation.
- Flaw – A permanent deviation in the pipeline shape properties according to API 5L.

Scope and Metrics

The approach noted above evaluates current versus new or emerging developments associated with bedding and padding or related protection for construction situations ranging from hard rock through soft soil in reference to reduced cost and enhanced productivity, safety, and reliability. This open-ended scope was contractually focused in reference to three site visits to gather data with the expectation of comparing the just-noted two current technologies with the emerging layered-backfill technology.

The work scope proposed addressed the matrix of equipment and construction situations as identified in Table 1. The emerging layered-backfill technology was addressed in reference to KNI equipment known as Dynapad[10]. Existing technology that was to serve as the reference for comparison to existing practices was through comparison to Rock Shield[4-7] in one of its several commercial forms and the Ozzie Padder[13]. The decision to use the Ozzie Padder as the reference for current technology reflected the view in planning this project that this equipment was in widespread use. Comparison of these practices was proposed in the framework of the 3-by-3 matrix of situations in Table 1, with eight combinations proposed for consideration.

New technology was considered in regard to pipe support methods, for which sandbags were taken as the reference for comparison. New also technology was considered to the extent it became evident during the course of the project, and was available for observation and/or evaluation. Aspects considered to varying degrees include geotextile fabric to stabilize the ditch,

in-the-ditch markers as a means to limit mechanical damage[2], in-the-ditch crusher technology and related mobile crushers as alternatives to existing equipment, and alternative practices for use with trench breakers on hills as a means to stabilize the ditch.

Table 1. Matrix of construction scenarios targeted for evaluation

Machine/System	Construction Situation		
	Rock[3]	Mixed	Soil
Dynapad	√	√	√
Rock Shield	√	√	
Ozzie Padder	√	√	√

Five parameters were considered as quantitative metrics of quality in planning these projects, which could be used to infer relative measures of safety and reliability including:

- absence of permanent pipe shape change or mechanical damage,
- absence of coating damage,
- extent of fill compaction below the pipe,
- quality of support and its effect on future pipeline functionality, and
- quality of bedding, padding, and backfill around pipe.

The first and third of these metrics are identical regardless of the support system, be it sandbags or other benches designed to avoid pipeline contact with the bottom of the trench. The second and fourth metrics reflect the interaction between the support scheme used during construction and the initially uncompacted bedding below the pipeline.

Three parameters were considered in the planning as absolute quantitative metrics related to productivity, including:

- speed forward,
- volumetric fill rate, and
- soil type.

These metrics were evaluated for a range of construction situations that ranged from soft ground through incorporate increasingly challenging situations, ending with construction through hard rock.

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[2] For discussion of such markers and their value in reducing third-party contact, see Reference 27.

[3] In planning, rock was taken as situations where the ditch needs to be shot, or cut with rock trenching equipment – the definition of mixed was recognized to depend on the spreads available, with the expectation that it would reflect frequent encounters with significant rock content in sizes 3 inches and larger – while soil referred to bottomland or rich organic farm acreage with light clay, but again depended somewhat on the spreads available.

Construction-Imposed Constraints

Data that can be gathered over the range of construction situations in Table 1 is constrained in practice by the equipment in use, which reflects the contractor's assessment of benefit in reference to productivity and safety consistent with the specifications for his project as set forth by the pipeline company he was working for. Empirical observation of some of the metrics noted above requires "hands-on" access to the pipeline during construction. The data that can be gathered also are constrained by site safety rules, and OSHA requirements related to ditch/trench safety. Finally, the data that can be gathered are constrained by safety related to the heavy equipment in operation along the ditch, downtimes for that equipment with ditch access as directed by the contractor, and the contractor's presence on the right-of-way. In all cases, safety requirements were set forth by the contractor in a safety briefing prior to entry to the right-of-way, which in each case indicated the need to adhere to safety-related constraints as directed from time to time by the contractor.

As entry to the right-of-way was subject to approval of the contractor and his presence therein, safety and other conditions dictated to obtain the contractor's approval for site access were adhered to. These right-of-way entry requirements typically limited hands-on observations to a few minutes prior to startup each day, to downtimes during tie-ins at sites remote to the tie-in, and to about 15 minutes during the break periods and at the end of the day's construction. Because the desire was to observe and evaluate construction as it normally occurs, being onsite but out of sight was essential to ensure typical practices were utilized. Being onsite for a period of a week or more also helped to ensure usual practices were used, as in some cases "special care" was evident early in some site visits.

As differences between soil types and the presence of rock could affect the comparison between proven versus emerging or new practices and equipment, ideally comparative data would be developed under identical field conditions. However, as the equipment or practices used on adjacent spreads was the choice of the contractor, the ideal scenario of head-to-head comparison was virtually impossible to achieve in practice. Nevertheless, an effort was made to obtain data under conditions where the comparison occurred on adjacent spreads under what appeared to be comparable conditions. Soil sampling was done by commercial laboratories as a guide to the nature of the materials involved. But as this reflects disturbed samples, and soils by their nature are variable, little can be said to ensure comparisons on even adjacent spreads were indeed comparable. For this reason, productivity is reported for each site visited in terms of forward progress and related metrics, along with an indication of the equipment on site and the practices in use.

The final practical constraint involves the project's timeline and schedule, and the need to identify construction projects that are consistent with this timeline and schedule and the unique needs of this project.

Task Structure and Report Organization

Meeting the project objectives for this work scope was accomplished in reference to four technical tasks and a reporting task, as follows:

1. identify spreads that illustrate the problems encountered and the capabilities of current

and emerging technologies and practices,

2. develop field protocols to quantify the above-noted metrics,
3. gather qualitative and quantitative data characterizing the above-noted metrics, through field observations and discussions with industry experts, observing the strengths and weaknesses of current, emerging, and new equipment or practices,
4. evaluate and trend the data and compare current versus emerging or new bedding and padding methods, and related construction technologies, and,
5. report the results quantifying improved pipe protection and decreased construction created pipe/pipe coating damage achieved with emerging or new pipe support and padding/backfill equipment and practices.

The report develops in the sequence of the just noted tasks. The next section focuses on the results, beginning consideration of the sites and spreads, and continuing with consideration of the protocols developed for on-site measurement. Thereafter, each of the spreads visited are discussed along with a summary of the results. The next section evaluates the data and identifies and discusses trends, leading to the last section which summarizes the work and presents the project's conclusions. The details in all cases are relegated to appendices. Appendix A presents the field measurement target protocol, while Appendix B presents the target report format. Appendix C presents the site visit reports, while appendix D presents the soils reports as determined for selected sites. Finally, Appendix E presents results done to better understand the structural performance of benches made of polymeric foam.

Results – Tasks One and Two

Metrics and Site Protocols

The objectives of Tasks One and Two were to develop practical field measures to characterize the high-level metrics indicated in the section titled Scope and Metrics and then develop protocols to consistently capture the data and report it.

Productivity can be directly measured in regard to forward speed by estimating forward daily progress through odometer estimates made along the right of way coupled with a daily estimate of the time spent in bedding and padding. Productivity also can be directly measured in regard to volumetric fill rate using forward speed coupled with periodic estimates of average trench depth and width. In contrast, soil type and ditching characteristics cannot be so simply quantified, nor can the size of the aggregate present. Given the variability evident along a given right-of-way, such variability precludes characterizing soil type unless statistically designed sampling is used, the cost for which was well beyond that possible within this project. Accordingly, soils were sampled to the extent possible using standard sieve methods and a geological assessment of the materials present using commercial laboratories near the spreads.

High-level metrics involving construction-related potential benefits for safety and reliability focused on permanent shape change and mechanical damage, along with coating quality. Parameters associated with potential benefits involving improved benching practices considered the effect of pipe support on pipeline functionality and fill compaction. Five qualitative measures were used to characterize these high-level metrics in regard to safety and reliability. Visual observations were used to identify obvious flaws in regard to denting and other local

permanent changes in pipe shape such as mechanical damage. Likewise visual observations were used along with touch to identify flaws in coating quality. These sensory-based measures in most cases were backed up by widespread checks in coating quality using a local jeeping capability that was functional even though part of the pipe had been bedded or partially padded. Results developed in this project were evaluated in light of literature data, oral communications, and related analysis[28-34] considering the effect of backfill mass, angularity, and other factors on coating damage.

Visual observations were made under the pipe whenever construction conditions permitted such, to identify the extent of bedding flow under the pipe, which occasionally was photographed to document these observations. As a gap was observed below the invert of the pipe as the bedding process advanced along the pipe-string, one can conclude that a gap exists at least initially at this location. However, based on soil mechanics considerations[35], continued flow of bedding material under the pipe appears to be forced by the weight of the padding and subsequent backfill, particularly in less viscous fill materials. Order-of-magnitude analysis is introduced later to supplement visual observations of the role of bench compression and failure on the extent of fill compaction below the pipe, and its effect on pipeline functionality. Finally, visual observations were made in regard to the extent of compaction, which were supported by observations of impact penetration in these areas when permitted by the contractor. The sum of these observations and analyses results were used to contrast the quality of bedding, padding, and backfill around pipe for the variety of equipment and practices evaluated across the range of soil conditions considered.

A protocol was developed to consistently implement the empirical observations and measurements, a copy of which is presented in Appendix A. As can be seen from this appendix, this protocol is rather comprehensive. While not a formal part of the protocol as they reflect random occurrences, from time to time larger rocks can slip from the spoil pipe being worked for fill material suitable for bedding and padding. Contact when it occurs with pipe-string is announced by a gong-sound that propagates along the pipe-string and motivates examination of the coating for damage and immediate in-situ repairs. The larger the impact, and more likely the damage, the louder the sound that announces of the contact. When contact occurred, care was taken to observe the size of the rock and its angularity, the likely elevation above the pipe based on the location of the padding or other supporting equipment, and the nature of the coating damage if any was evident. Finally, where the opportunity occurred along the right-of-way to evaluate the sensitivity of the coating to backfill damage more broadly than addressed in the protocol, data were developed. Usually this involved evaluations made on short lengths of pipe discarded after a tie-in, which were not yet cleared from the right-of-way. Where such scrap was found, various sizes of rock and/or degrees of angularity were used in an ad hoc evaluation of the sensitivity of the coating to impact, penetration, and/or scratching.

Field Reporting Format

A reporting structure was developed to ensure the consistent recording of the measurements and observations developed in reference to the protocol for empirical observations and measurements presented in Appendix A. An example of the reporting structure the form developed for use in field reporting is presented in Appendix B. As can be seen there, the data scope covered in this reporting is extensive. Where results were developed beyond the field measurement and observation protocol, they were reported independent of this form.

Site Selection Criteria

The selection of spreads began with the award of contract. It was idealistically planned to develop a list of potential sites within two months after award of contract based on FERC-approved construction underway nationally. Criteria planned for selecting spreads included a minimum length of 10 miles[4], along with consideration of the routing and soil and rock anticipated on the spread. Another key in selecting spreads involved the construction equipment and practices employed by the contractor, the desire being to observe as many elements noted in Table 1 on different spreads of the same construction project. As indicated in Table 1 the desire was to include a range of soil and rock situations, tabulated therein as rock, mixed, or soil. The desire also was to consider Dynapad in comparison to Ozzie (or other padders) and Rock Shield. Consequently, the potential suitability of FERC-approved spreads included evaluation of likely soil types based initially on USGS maps with follow-up planned to include pipeline company survey data and discussions with the selected contractors to identify their preferred equipment and practices.

A cursory review of FERC-approved pipelines on the books and under a construction contract done in planning this project indicated a two-year-long contracting period, with three site visits targeting projects involving multiple spreads to maximize the value gained from each visit. Superimposed on selecting projects and spreads was the complicating effect of visits during periods of winter constructions, as the time of year can influence the effectiveness of some construction equipment and practices and alter the properties of pipeline coatings. Consequently, when during the year construction was projected to occur became a potentially important factor in selecting sites. This introduced the need for some potential compromise when selecting spreads when experience indicated seasonal differences might override the other considerations.

However, the primary consideration in spread selection was the contractor's planned use of equipment. Whereas correspondence with KNI during planning indicated its Dynapad machine and related technology would be present for evaluation on a variety of spreads[(36)], such that equipment in use was anticipated to be a secondary factor, the reality was that only a very few spreads could be identified where it would be used with certainty along with its related new technology. It became clear during spread selection that when Dynapad was used there was only limited or no use of what was perceived by KNI to be new technology, such as their foam benches or geotextile fabric. The decision to use such technology remained that of the pipeline owner, and his contractor, with reticence to employ new technology reflecting the view that it either was untested or proven – or there was reason to question its safe use or value.

Consequently, the site selection process was reduced to consideration of spreads that could be found where Dynapad and other new or emerging technology was in use, followed by evaluation of the incremental knowledge gained from such a visit. While it was planned to select sites and stage visits to projects and spreads to meet the needs of Table 1, the planning process was

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[4] The minimum length of 10 miles was noted in the proposal as one approach to average out the effect of soils variability on productivity and safety and reliability. As time passed it became evident that the inherent variability in soils and geological formations was large enough in some areas that it could not be averaged-out so simply. More importantly, it also became evident that overall construction productivity was dominated by the effects of hills, which primarily reflects the need for tie-in welds to join the segments of pipeline strung together between areas where curvature reversed. As such, the minimum length of 10 miles became a secondary consideration.

reduced to selecting between a few projects that marginally suited the needs of the project. As the data so generated were limited, the number of spreads targeted was increased beyond the three sites addressed in the project's planned scope with a view to bridging some gaps in the database, with budget reallocated accordingly.

Finally, the process of selecting and accepting spreads can be influenced by the need to meet programmatic milestones in support of making task deliverables. For this project this aspect was secondary to the desire to address the technical concerns that underlie the range of soil types and existing and emerging construction practices noted in Table 1.

Sites Selected and Site Descriptions

Task 1 delivered a series of sites that reflected routings and construction practices consistent with the expectations of Table 1. A total of five sites were developed and visited, as detailed in the ensuing paragraphs.

Site One – Market Link (Transco/Williams)

The Market Link Project involved construction of a 42-inch diameter pipeline coated with fusion-bonded epoxy through eastern Pennsylvania and western New Jersey. The wall thickness varied as required for road crossings and class changes, consistent with class location and code requirements.

Construction on multiple spreads by different contractors using Dynapad and Ozzie padders made this a potentially very useful site. This also was an attractive site as the owner and the contractor on one spread agreed to the use of preformed foam benches and the use of geotextile fabric at least over a short run of the pipeline. The spreads involved construction in soils of mixed clay and rock through quite hilly terrain. Figure 2 presents a sequence of photographs that capture features along the right-of-way, from the ditching through the construction and restoration for this project.

The ditch on all spreads was created with backhoes and because of the large rocks present had variable width and occasionally uneven depth. Because of this, and the larger diameter of the pipeline, there was a significant amount of material required to meet the bedding and padding specifications. Spoil piles were created over an existing pipeline along some portions of the construction. While there were differences in the mix of soil and rock in these spreads, the difference was not significant. Rock sizes ranged from usual rounded stone and boulders, in sizes that in some cases were up to several feet across. The relative fraction of usable material in the spoil piles that lay adjacent to the ditch that was acceptable according to company specification was roughly 60 to 75 percent by volume, depending on location along the right of way.

These spreads were well suited to the purposes of this project as they involve two different machines for padding pipelines, both of which were designed to extract fines from native backfill located adjacent to the pipeline. The downside for these spreads involved the short notice of their availability just prior to initiating the project contract. This limited the time on these spreads and the preparations possible for these visits.

In Progress

a)

b)

Figure 2.

Site Two –Expansion (Kern River/Williams)

This project increased Kern River system's capacity by construction of a 36-inch diameter 740-mile-long looping through Wyoming, Utah, Nevada and California. The line pipe wall thickness varied as required for road crossings and class changes, consistent with class location and code requirements, and was coated with fusion-bonded epoxy whose. This construction parallels the existing mainline and was laid in that right-of-way. Four spreads were active during the period of the visit, starting with Spread 7 centered at Mesquite, Nevada, Spread 8 centered at Primm, Nevada, and Spreads 9 and 10 centered at Barstow, California. The right of way ranged from hard rock in some of the upstream areas, to sand in areas of California. Figure 3 presents a sequence of photographs that capture features along the right-of-way, from the ditching through the construction and restoration for this project.

The ditch on spreads involving softer soils and sandy conditions was created with backhoes, while that through the rock used mechanical trenching, although a few short sections were shot. The transition from rock into more workable soils appeared to occur rather abruptly in most cases. Where the ditch was machine cut, it was rectangular and sized consistent with regulatory requirements and company specifications, and the spoil was rich with fill material of a consistent size and shape that comprise acceptable backfill. In the short sections where the rock was shot, the ditch was randomly shaped with depth to comply with regulations and width much wider than required by company specifications, and was without useful spoil. Trenching through the softer soils provided rich spoil. The depth of the trench was consistent and as required by regulations. The width also was rather consistent and wider that required, being apparently controlled largely by the strength characteristics of the soil. Generally, the spoil piles were laid away from the existing pipeline.

Where the ditch size matched regulations and company specification, the required backfill was minimized, but where the ditch size was variable and much greater than necessary, there was a significant amount of material required to bed and pad the pipeline. In areas that involved a machined ditch or the construction was through softer soils, the relative fraction of usable material in the spoil piles created was virtually 100 percent. In contrast, in the short sections where the rock was shot there was virtually no useful material. However, more than ample useful material was available to bed and pad these areas from the spoil piles adjacent to these sections.

Construction on multiple spreads by different contractors using Ozzie and Outlaw padders made this a potentially very useful site. This also was an attractive site as the owner and the contractor on the rocky spreads were using sprayed foam benches and foam padding up the walls during lowering-in. The spreads involved construction through quite hilly terrain, which necessitated many tie-in welds to join previously welded pipe strings. These spreads were well suited to the purposes of this project as they involve two different machines for padding pipelines, both of which were designed to extract fill material from native backfill located adjacent to the pipeline.

Site Three – Patriot (Duke)

The Patriot project is part of the construction underway as part of the East Tennessee Gas Project (owned by Duke Energy). Multiple spreads were working between Tennessee, centered near Bristol, and Virginia, centered near Wytheville. The construction involved 24-inch diameter line pipe whose wall thickness varied as required for road crossings and class changes, consistent

In Progress

a)

b)

Figure 3.

with class location and code requirements. This line pipe was coated with polyethylene tape. Figure 4 presents a sequence of photographs that capture features along the right-of-way, from the ditching through the construction and restoration for this project.

Construction used Dynapad for bedding and padding, but the company was not interested using KNI's preformed foam benches or geotextile fabric, even over a short run of the pipeline. The spreads involved construction in soils of mixed clay and flat and rounded rock through moderately hilly terrain.

The ditching was done using with backhoes and occasionally had variable width and uneven depth. The soil varied from soft clay largely free of rock, through quite rock material that ranged from rounded through flat. The ditch was occasionally quite wide in contrast to the requirements of the minimum company specifications, and also showed some large variations in depth. For this reason in some places there was a significant amount of material required to bed and pad the pipeline. There were long runs free of rock, and a few stretches that were quite rocky, with the transition between these areas being quite abrupt. There were differences in the mix of soil and rock in these spreads, which depending on the location were quite significant. Where rock was present, the sizes ranged from smaller rounded stone and boulders, to flat rock that occasionally was several feet across. The relative fraction of usable material that was acceptable according to company specification where rock was present was roughly 60 to 70 percent by volume.

These spreads were well suited to the purposes of this project as they presented the opportunity to observe Dynapad to balance the quite extensive opportunity to observe the Ozzie padder provided on the Kern River project.

Site Four – Cardinal (Marathon)

The Cardinal Pipeline construction runs through spreads from near Columbus Ohio south toward the Ohio – Kentucky border. This hazardous-liquid pipeline was constructed from 14-inch diameter line pipe with wall thickness that as usual varies as required for road crossings and class changes, consistent with class location and code requirements. The line pipe was coated with thin-film FBE. Figure 5 presents a sequence of photographs that capture features along the right-of-way, from the ditching through the construction and restoration for this project.

Construction involved spreads where the bedding and padding was done using an Ozzie padder. The spreads involved construction over moderate rolling hills in soils of mixed clay and rock, through some heavily rocky areas. Where rock was present, the sizes ranged from smaller rounded stone and boulders over a broad range of sizes, through some large flat and quite angular sharp rock where the construction ran through the Hocking Hills.

Ditching on all spreads was done with backhoes with spoil piles created either side of the ditch. Because of the large rocks found in some stretches, the ditch had variable width and depth, with occasionally quite deep sections. Because of this, there occasionally was a significant amount of material required to bed and pad the pipeline. There were significant differences in the mix of soil and rock along these spreads, which depending on the location were quite significant. The relative fraction of usable material that was acceptable according to company specification where rock was present was roughly 50 to 60 percent by volume.

In Progress

a)

b)

Figure 4.

These spreads were well suited to the purposes of this project as they involved use of foam-sprayed trench breakers, which for some would be considered new technology, and provided for observations of bedding and padding under wet conditions.

Site Five – Expansion (Colonial)

Construction of the Colonial expansion runs through portions of Tennessee with topography and geology similar to that of the Cardinal Pipeline. Because this construction was concurrent in time with the Patriot project and also ran through Tennessee, these multiple spreads could be accomplished through one visit. This construction used Ozzie padders through similar conditions as the Patriot construction done using Dynapad, which made this a potentially useful site. These spreads involved soils of mixed clay and rock through quite hilly terrain. Unfortunately, the construction did not present enough rock to necessitate much use of bedding and padding equipment, nor was there much opportunity to significantly add to the prior observations. Consequently, after a brief site visit to assess the potential value of further observations, the visit was abandoned.

Observations, Data, and Discussion – Tasks Three and Four

The objective of Task Three was to gather qualitative and quantitative data characterizing the metrics identified earlier, through field observations and discussions with industry experts, observing the strengths and weaknesses of current, emerging, and new equipment or practices. The objective of Task Four was to evaluate this data, and develop trends. Photographs that support the following sections can be found in the corresponding field reports as filed without editing or concurrence of all involved that are presented in Appendix C[5]. Additional photographs can be found in Figures 2, 3, 4, and 5 for Sites one to Four, respectively.

Site One – Market Link (Transco/Williams)

As indicated earlier, this construction involved a 42-inch diameter line pipe with a heavy brown-coat FBE on an 0.429-inch thick wall. The ditch on all spreads was created with backhoes and because of the large rocks present had variable width and occasionally uneven depth. Because of this, and the larger diameter of the pipeline, there was the potential to need a significant amount of material to meet the bedding and padding specifications. The spreads active were being built by different contractors, one using an Ozzie padder and another using a Dynapad. Because these spreads were active through areas involving rock just as this project was initiated, the planning and time on-site was limited. Consequently, the observations focused on bedding and padding, which also was the focus of the measurements and reporting. This work was completed prior to completion of the protocol and reporting forms presented in the appendices, and in part served as a guide to improve what had been anticipated for these aspects. The majority of the observations reflect operations with largely dry spoil. In contrast to areas where the spoil was dry, wet spoil appeared to cause problems with most aspects of the bedding and padding process.

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[5] Generally the changes between the reports as filed and as presented in the following sections reflect editorial and style changes. There are, however, a few areas where the content changed as details became better defined.

In Progress

a)

b)
Figure 5.

Dynapad spread

Equipment and Personnel

- One Dynapad padder
    - One backhoe serving the padder
    - One bulldozer
    - Four people involved in bedding and padding operations, and related restoration.
    - One padding/backfill inspector
    - One operator on Dynapad
    - One operator for the backhoe
    - One operator for bulldozer
    - One site manager walking with equipment
- An inspector was available during bedding and padding, and backfill operations

Supports (Sandbags)

- The typical number of sandbags varied from support to support, ranging from three to six in the soft soil areas. Higher numbers of sandbags was used in instances where rises, sags and turns occurred to accommodate inconsistencies in ditch depth and places where bends in the pipe-string apparently did not neatly match the ditch profile.
- The center-to-center distances varied widely from terrain to terrain. In rocky and hilly sections the bags were spaced more consistently.

Supports (Foam Benches)

- Foam benches were set over the ditch bottom on a short stretch of the right-of-way in advance of lowering-in through that section. These benches were precast and apparently made of polyurethane foam whose formulation was not available. All benches had a fixed thickness, width and length, being the order of several feet long and roughly one foot square. As they were light-weight and easily handled, their placement would be simple and require only a light truck and two laborers (driver and setter). By virtue of their rather disorganized placement, a laborer would be needed to reset them during lowering-in. Their constant thickness and width would result in inconsistent support to the pipe because of the variable depth of the trench due to the presence of large rock encountered during ditching.
- One truck would be positioned ahead of the lowering-in crew. They were responsible for the placement of the sandbags in the trenches for the benches. The initial two days of observation yielded terrain that was sandy and rocky in stretches. When the soil was consisting mostly of fines, a few sandbags were placed great distances from each other and in other places the pipe simply laid on the trench floor. In the rocky stretches, the sandbag count and frequency increased to match the terrain. No attempt by the padding crew was made to adjust any pipe supports that might have not seemed sufficient.

Breakers

- There was no opportunity to observe breakers during the short time on the spread.

Bedding and Padding Operations

- The Dynapad is an inclined vertically stacked processor of spoil that uses multiple screens to separate and grade spoil, and by arrangements within the unit deposits successively coarser fill material sequentially into the right-of-way. Dynapad is gravity-fed, operating over the pipe-string while attached to and suspended there from a "mast" attached to a conventional side-boom. Provisions are included to maintain the screening unit or "mainframe" more or less horizontal, and to rotate this unit. The shaking or vibrating screens are steeply inclined (~45° in optimal use, to limit dynamic screen blinding), being fed by a conveyer from a holder that collects fill material from hopper. Primary separation occurs above the hopper through use of steel bars with a clear spacing that passes material about 5-inches on one dimension. These bars run across the full length of the hopper. These bars serve to reject rocks and clumps of fill material larger than this size, and can be raised to a vertical position to dump debris laying these bars into the already padded ditch. This helps limit static blinding of this primary screen. As with the screens below, the barred entry to the hopper lies at a steep angle to horizontal, which helps gravity move oversize spoil off the back of the screen or hopper. Spoil passed through the bars is transferred from the holder onto a conveyor belt to increasingly finer screens. The clear pitch of the first screen is designed to pass material the order of two inches on a side, measuring about 2.25 by 2.25 inches, while the clear pitch for the second screen measured about 1.5 by 2.25 inches, the latter dimension being parallel to the trench. The positioning of the screens and the internal operation of the mainframe causes the smallest to fall first onto the pipe. Increasingly coarser material is deposited sequentially over the length of a few feet along the pipe-string. Thus, soil and rock larger than the last screen but smaller than the first falls onto the fines passed by the last screen, while material not passed by the bars falls onto the previously deposited padding as it falls off the back of the hopper. The incline angle of the screens coupled with movement of the screens and gravity controls the size of the material passing the screen, such that the material passed tends to be smaller than the clear pitch of the screens. These parameters also cause the larger material to shift along the screen until it eventually falls to the next screen or onto the pipe-string. Where ample fines are accessible to the backhoe feeding the padder, the deposit off the last screen can create a layer of cover whose depth ranges from six to twelve inches deep (on average), which is followed by successive layers of increasingly larger fill material and rock, the last comprising material that did not pass the bars above the hopper. Because the hopper is fed by backhoe, spoil can be selected whose maximum size suited the requirements for the job.
- The size of the trench relative to the pipe was measured in several areas where the pipe had been lowered-in. In some places the width of the ditch was two to three times the diameter of the pipeline. This was much wider than the minimum width based on company specifications, which based on discussions with help on-site typically required twelve inches more than the outside diameter of the pipe.
- Based on limited site observations, the Dynapad was used over stretches where rock was present. Stretches of soil where minimal to no rocks were present were padded with backhoes from the spoil pile based on comments from the crew.

- Forward progress was measured over several rocky stretches, which on average indicated the Dynapad produced 350 feet per hour on average, with some variation evident in speed depending on spoil conditions.
- Because of the reach of the backhoe, the Dynapad can feed its hopper from a wide range of spoil, which for this spread permitted the pipe-string to be padded in one pass. The layered backfill from this single pass developed bedding, padding, and cover for the pipe-string of at least two feet, with upwards of three feet deposited in some locations.
- The ability to select fines by loading independently through a backhoe means that with appropriate spoil selection startup can proceed with only fines deposited into the ditch. Backhoe operator skill in this context is essential to limit damage to the coating until forward progress develops the layer onto which the coarser fines and other material are subsequently deposited.
- Because the last screen deposits fines onto an already existing layer once steady-state operation develops, and because the spoil was dry, the fill material flows freely onto, around, and underneath the pipe leaving little unfilled the area except below the invert. Continued flow of the fill material appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void.
- The padding operation involved one Dynapad padder, one backhoe, and one bulldozer. No tie-ins were done while on-site, so there was no way to observe how such areas were dealt with.

Layered Backfill, Coating Condition and Possible Damage

- Because of the limited preparation time, there was no opportunity to obtain jeeping equipment. However, during start-stop cycles, the contractor allowed entry to the ditch, which facilitated periodic evaluation of coating quality as well as the nature of the layered backfill. For this job the light-weight Dynapad could work on either on the shoulder of the ditch, with access to the main spoil pipes deposited over the two hot pipelines operating in this right-of-way. The initial screen's mesh size and gravity feed of the material that drop to and impact the pipe off the last screen are anticipated to minimize coating damage and develop a compactable layer because of the rather small size of the fines deposited off the first screen. This was observed, along with the anticipated layered backfill created by successive deposits due to the multi-screen design of this machine.
- The fill material off the fine screen dropped around the pipe, with the hopper fed until the pipe-string was covered, after which the fill material were observed to flow forward enveloping the pipe-string over a distance of several feet. No operator "technique" was necessary, as the amount of fill material available at startup did not require forward motion to supply feed for the hopper, nor was technique needed to ensure that material adjacent to the pipe-string was comprised of fines. Flow of the fill material forward along the pipe-string once the pipe-string is enveloped is controlled by soil mechanics through the angle of repose for the soil[35], which depends on the nature of the soil, including the size and to a lesser extent the shape of the fill material. A bedding and padding machine that provides for these aspects should supply well compacted fill that flows around the pipeline, with the least chance for coating damage. Significantly, forward flow of the backfill and the natural selectivity for coarser material to roll down the slope created by the angle of repose has been understood for decades as fundamental

to success in bedding and padding[37,38], and a design parameter for such equipment. A major advantage of the Dynapad lies in its ability to easily select spoil that is high in fines and deposit that material without the need to move forward along the ditch, as this facilitates startup of the bedding and padding process without concern for coarser material impacting the pipe.

- While contact with the pipe is necessary for damage, whether or not damage is done depends on the resistance of the coating to impact and other forms of contact as well as the energy and the nature of the contact. Nevertheless, a machine that limits contact is a hedge to avoid coating damage. So long as adequate cover is developed over an initial section of the pipe, and subsequent fill material flow forward and envelop the pipe, the fill added should cause no chipping or other coating damage. Success in this context is largely dependent on fill that flows freely, which occurs most easily for dry fine fill material.
- Physical inspection showed the initial layer deposited comprised largely earth for this jobsite. The leading edge of the fill material was loosely compacted, but a foot back where additional material overlaid the fines, physical inspection of the fill deposited over the crown of the pipe-string showed the deposit was compacted.
- Physical inspection where the fill over the crown of the pipe was removed as possible during period stops-start cycles showed a coating that looked as it did prior to the bedding and padding process, with no evidence of nicks or chips.
- Padding material was not obtained for sampling at this site due to the limited time available to facilitate such studies.
- The depth of the padding developed because the hopper can be filled without forward progress coupled with the double layering of increasingly coarser fill material keep large rocks coming off the back of the hopper from reaching the crown of the pipe-string, and appeared to likewise limit this during subsequent backhoe-backfill operations.
- While not specifically observed, the Dynapad operator indicated that on a good day, and with a skilled backhoe operator, upwards of 9000 feet could be covered over flat stretches during a typical day-long shift. This claim cannot be substantiated and seems extreme, and is included here only for the sake of completeness.
- In one short stretch through a sag area, where because of the topography the spoil was wet, the hopper appear to be prone to clog, which slowed the process and limited the flow of fill material, with some clumping being evident in the material deposited off the last screen.
- Areas where the ground was hilly revealed that the design of Dynapad limits its motion to one direction unless its mainframe was rotated. Likewise, if it is traversing hills with widely varying angle, the efficiency of the machine appeared to vary. However the machine provides for adjustment to overcome this, where the operator chooses to make such adjustments. Also where working steep hills without adjustments to level or rotate the mainframe there is the possibility of large rocks falling off the bars on top of the hopper and rolling past the padding operation onto bare pipe. This can be remedied by adjustments as needed, or by working machines in opposite directions such that gravity causes the large rocks to roll back off the hopper toward the already padded pipe. Such is the case for all machines, becoming more acute as the incline-angle of the screen is increased.

Backfill Operations

- The backfill process was accomplished with a backhoe drawing fill material from the spoil piles. The padding had sufficient depth to preclude large rocks from reaching the crown of the pipe-string.
- A bulldozer was used to top-off the trench after the backhoe was finished.

Ozzie Spread

Equipment and Personnel

- One Ozzie padder
- One bulldozer creating windrows of spoil serving the padder
- One backhoe as required to supply the bulldozer as needed
- Four people involved in bedding and padding operations, and related restoration.
  - One padding/backfill inspector
  - One operator on the Ozzie
  - One operator for the backhoe
  - One operator for bulldozer
  - One site manager walking with equipment
- An inspector was available during bedding and padding, and backfill operations

Supports (Sandbags)

- Although the contractor was different on this spread, practices associated with sandbag benches were similar to the Dynapad spread. Foam Benches were not used over any portion of this spread.

Breakers

- As for the Dynapad spread, there was no opportunity to observe breakers during the limited time on the spread.

Bedding and Padding Operations

- The Ozzie Padder is an inclined in-line integrated loader and processor of spoil. It couples a single shaking or vibrating screen that is fed by a conveyer through a chute to a loader located at the front of the machine. The screen for this job had a clear spacing of about 2 inches on a side. As for Dynapad or any screen-based system, the incline angle of the screen coupled with movement of the screen and gravity controls the size of the material passing the screen, such that the material passed tends to be smaller than the clear pitch. These same parameters also cause the larger material to shift along the screen until for the Ozzie it is deposited on the shoulder of the ditch in the wake of the padder. The chute on the Ozzie lies behind an articulated "mouth" at the front of the machine that provides limited manipulation to broaden access and/or aid selection of backfill material. The machine operates on the shoulder of the ditch parallel to the pipe-string, feeding select fill to the pipe-string by a conveyer table that collects fill material from the screen and delivers it to the ditch by extending the table from the machine toward the ditch. Because the spoil processor is in-line and integrated to its loader, access to spoil is controlled by the fill material available from a linear track through the spoil windrow. For this reason, the spoil available in the windrow was enhanced by "roaching" the spoil

using a bulldozer, adding material where possible and narrowing the windrow to better match the mouth of the padder. Very large rock several feet across was selectively removed during this process. However, in contrast to the feed to the Dynapad where large rock was selectively avoided by the backhoe operator, many quite rocks (some up to two feet across) remained in the windrow. This heavy-duty machine very efficiently separated these large rocks from the useful material in the spoil, conveniently dumped this unsuitable material in the wake of the machine. For this job the fill material available from the spoil forced a second pass, and sometimes third pass, to provide the specified bedding depth and padding cover. Because the machine very efficiently separates useful material from the spoil, little useful material remains after a pass through the windrow, leading to diminished returns from a second or third pass unless material is added to the windrow or the windrow reshaped with spoil that was not used on a prior pass. It follows that efficiency in padding is controlled by the length conveyer table, to facilitate access to spoil further from the ditch, and the amount of fill material that are available from the windrow of spoil. Efficiency is also influenced by the quality of the ditching, as heavier versions of this machine must remain well off the edge of the ditch. For this job, the largest Ozzie was used, the weight of which kept it off the main spoil pile that during trenching was placed over two adjacent hot lines in the right-of-way. This too affected efficiency, as it limited the supply of available spoil. Other factors include the large diameter of this pipeline and the uneven larger ditch due to the rock, both of which contribute to the amount to acceptable material required to meet company-specified cover.

- Bedding and padding reaching the pipe for the Ozzie appears to be homogenous in size and constituents throughout the cover. The cover appeared to be softer and more easily penetrated by large rocks that occasionally are placed over the cover as the ditch is backfilled.
- The size of the trench relative to the pipe was measured in several areas where the pipe had been lower-in. In some places the width of the ditch was more than two but much less than three times the diameter of the pipeline. This was wider than the minimum width based on company specifications, which based on discussions with help on-site typically required twelve inches more than the outside diameter of the pipe.
- Based on limited site observations, the Ozzie was used over stretches where rock was present. Stretches of soil where minimal to no rocks were present were padded with backhoes from the spoil pile based on comments from the crew.
- Forward progress was measured over several rocky stretches, which on average indicated the Ozzie produced 300 feet per hour. Where multiple passes were needed, productivity dropped in proportion to the number of passes made. Where multiple passes were used, a backhoe occasionally was used to transfer spoil to the side of the ditch being padded. Where the spoil was rich in fines, a single pass provided bedding, padding, and cover for the pipe-string to depths that reached one to two feet.
- Once the bedding and padding process had started, fill material off the screen flowed freely underneath the pipe, with little unfilled the area except below the invert. Continued flow of backfill appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void. The fines in the fill appeared to drop onto the already deposited material and remain in place,

whereas the larger material rolled off these fines ahead of what remained close to the pipe, and into the ditch bottom. Consequently, while not inherently designed to produce layering of the deposited fill, in steady-state operation the coarser material "rolled" ahead of the fines to fill areas remote to the pipe, while fines remained near the pipe. However, such did not occur during startup when the generally uniform fill material fell or was projected off the conveyer table randomly onto the pipe. During this startup and over the first few feet of travel larger rocks that passed the screen could fall directly onto the pipe-string.

- During the startup phase, the fill material serving as bedding flowed freely underneath the pipe, with little unfilled the area except that below the invert. Continued flow of the fill material appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void.
- No tie-ins were done while on-site, so there was no way to observe how such areas were dealt with.

Backfill, Coating Condition, and Possible Damage

- Because of the limited preparation time, there was no opportunity to obtain jeeping equipment. However, the start-stop cycles associated with repositioning of the machine for a second or third pass, the contractor permitted brief entry into the ditch. This facilitated periodic evaluation of coating quality as well as the nature of the backfill. For this job the Ozzie worked the line of the lesser spoil piles laid on the side of the ditch away from the two hot pipelines, or occasionally from an elevation a several feet above the shoulder of the ditch, up to as much as about six feet for the operations observed. The screen's mesh size and conveyer table/gravity feed of fill material showed all material passing the screen impacted the pipe during startup of the bedding and padding operation. Thus, rock whose size approached the clear pitch of the screen contacted the pipe-string during startup, with occasional impacts occurring squarely at the crown. However, while not inherently designed to produce layering of the deposited fill, during steady-state operation the coarser material "rolled" ahead of the fines to fill areas remote to the pipe, while fines remained near the pipe. Industry experts associated with companies that sell or operate such equipment note this inherent property of the fill material as a key to the success of such equipment[(e.g., 37,38,39,40)]. However, during startup the rolling behavior does not occur. Instead, the generally uniform fill material falling or projected off the conveyer table randomly contacts the pipe. This was observed during startup and over the first few feet of travel, with the larger rocks that passed the screen fall directly onto the pipe-string, occasionally onto the crown of the pipe. It follows that little damage is anticipated during steady-state operation because the already present fines limit direct contact and the larger material rolls harmlessly down to the ditch bottom. However, damage might be anticipated during startup and the first few feet of the bedding and padding operation unless the spoil is roached selectively to limit this problem.
- Operators and personnel working with the Ozzie padder note that the richest zone of fines tend to lie toward the bottom and center of the spoil[(39.40)], such that an effort is made at startup to articulate the mouth of the padder into this area during the startup phase of the operation. Also during startup, this operator indicated damage can be limited by directing the flow from the conveyer table against the far wall of the ditch, filling that side with overflow onto the top of the pipe-string, followed by flow onto the now covered

crown to fill the side adjacent the padder, such that the flow into the trench does not impact the pipe.

- Thus, operator "technique" gained through experience or training can be important to maximize the amount of fines available at startup and minimize possible damage, while less is necessary during steady-state operation. This can be complicated by the fact that forward motion is needed to supply feed to the screen. As discussed for Dynapad, flow of the fill material forward along the pipe-string once the pipe-string is enveloped is controlled by soil mechanics through the angle of repose for the soil[35], which depends on the nature of the soil, including the size and to a lesser extent the shape of the fill material. Thus, any bedding and padding machine that satisfies these aspects should supply well compacted fill that flows around the pipeline, with the least chance for coating damage. Forward flow of the fill material and the natural selectivity for coarser material to roll down the slope created by the angle of repose has been understood for decades as fundamental to success in bedding and padding[37,38], and a design parameter for such equipment. While an important parameter, whether or not damage is done depends on the resistance of the coating to impact and other forms of contact as well as the energy and the nature of the contact. Nevertheless, a machine that limits contact is a hedge to avoid coating damage. So long as adequate cover is developed over an initial section of the pipe, and subsequent fines flow forward and envelop the pipe, the fill added should cause no chipping or other coating damage. Success in this context is largely dependent on fill that flows freely, which occurs most easily for dry fine fill material.
- Physical inspection showed the steady-state layer deposited by the Ozzie was a mix of small stones and earth for this jobsite. The leading edge of the fill material was loosely compacted, as was the material a foot or more back, in spite of additional material being overlaid. While physical inspection of the fill deposited over the crown of the pipe-string showed limited compaction, the weight of the eventual overburden deposited during final backfill and restoration is very likely to achieve high compaction. Because the operator recognized the importance of the startup phase to the quality of the fill material deposited during this phase, it was not possible to gain access to either the nature of this deposit, nor was it possible to observe the pipe's surface under conditions characterized by this aspect of the process. While unfortunate, the fact that this phase appears to be dependent on operator experience and skill suggests that such results, were they available, could not be generalized beyond the specific situation observed.
- Physical inspection where the fill over the crown of the pipe was removed was possible for steady-state operation at the conclusion of a padding run, or other stop-start cycle. Such examination showed a coating that looked as it did prior to the bedding and padding process, with no obvious evidence of nicks or chips.
- Padding material was not obtained for sampling at this site due to the limited time available to facilitate such studies.
- The depth of the padding developed is a clear function of the fraction of fill material available and forward speed.
- While not specifically observed, the Ozzie operator indicated that upwards of 7500 feet could be covered over flat stretches during a typical day-long shift on a good day, and with a skilled bulldozer operator (that perhaps was supported by a backhoe operator).

This claim cannot be substantiated and seems extreme, and is included here only for the sake of completeness.

- As for Dynapad, the opportunity existed to evaluate the Ozzie padding a short section running through a sag, where again because of the topography the spoil was wet. The screen appeared to be prone to clog, which slowed the process and limited the flow of fill material. Some clumping also was evident in the material deposited as it rolled down the leading face of the bedding and padding.
- As for Dynapad, areas where the ground was hilly revealed that the design of the Ozzie limits its motion to one direction. If it is going down a steep hill, there is the possibility of large rocks falling off the screen on top of the hopper and rolling past the padding operation onto bare pipe. This can be remedied through use machines working in opposite directions such that gravity causing large rocks to roll back off the hopper would continue their movement toward already padded pipe. Such applies to all padders, becoming more acute as the incline angle of the padder increases.

Backfill Operations

- The backfill process was accomplished with a backhoe drawing fill material from the spoil piles. The padding appeared to have sufficient depth to preclude large rocks from reaching the crown of the pipe-string.
- A bulldozer was used top-off the trench after the backhoe was finished.

Site Two – Expansion (Kern River/Williams)

Spread :

This involved 36-inch diameter line pipe with 0.429-inch wall and factory-applied brown-coat FBE. This pipe was laid in a largely machine ditched trench, although some short sections involved shot rock.

Equipment (padding operation)

- Three Ozzie padders – two model 200, one model 300
- Two Outlaw padders (support for Ozzies)
- One auger dozer (backfill)
- Two bulldozers (backfill and roaching)
- Approximately 14 people involved in this aspect of operation

Equipment (lowering in)

- Four side booms

Equipment (other)

- One paddle hoe (backfill for leveling later by bulldozers)
- Numerous small water trucks (counted 8 at one time; others in route returning and leaving, several large water trucks - Clark County requirement for dust control)
- One foam truck – crew of 3, technician (company), foamer and driver (contract)

Inspectors

- There was one inspector present at padding operation, but could not identify inspector at lowering-in for certain.
- Two FERC representatives and one Environmental representative (which were readily identifiable from other personnel on site)
- One green hat (biological monitor) focused on ground turtles and their habitat in areas of equipment operation, with several walking the right of way between operations.

Supports (Foam Benches Only)

- Polyurethane foam (two-part) supplied by subcontractor Pedero Pipe Support Systems (Alberta, Canada) www.pedero.com .
- Spacing was approximately 18 feet (paced by operator), with height ~18 inches, width ~12 inches, and length equal to the width of trench. The height and width approximate and variable, as the benches were spray-formed from top of trench.
- Discussion with technician of one truck indicated they can spray-form benches for an average of two miles per day – comprising approximately 590 benches at 18' spacing. Analysis of this rate suggests this estimate is high, as it corresponds to a bench per minute for a 10-hour day. This does not allow time to change supply barrels and seemed faster than the observed production rate evident over a brief observation period.
- Discussion with Peter Ellis (Operations Manager and son of company President) indicated the following facts:
- Two basic types: open cell and closed cell. Closed cell much better, open cell structure is more porous/pervious.
- Foam temperature due to exothermic chemical reaction was approximately 175°F.
- The foam "solidifies" in seconds, with strength developed over its cure time, which was 1 to 2 hours.
- The design density was set at 2.2 lbs/ft^3, leading to great compressive strength (although localized failures evident from time to time suggests otherwise). Design density is based solely on diameter/wall thickness (weight) of pipe.
- Decomposes under UV light (sunlight) and water saturation (reference to breakers), but this occurs over a great deal of time. Discoloration of outer surface almost immediate, which was explained as being caused by sunlight.
- Density can be altered by design, but not at site as the chemical makeup for this property is established and then batched into barrels at the home plant, from where the material is trucked to the jobsite.
- Although the benches (pillows) can be sprayed from trench top, pre-made or shot into plastic/tarp bags, this job used in-situ sprayed benches.
- This spread also used sprayed foam as a reverse rock shield, as a layer of foam up to a few inches thick was sprayed up the rock on the trench wall opposite the side from where the pipe was strung.

Lowering-in with relation to benches and reverse rock shield

- In a flat straight pipe runs, most cases showed the benches supporting the pipe uniformly and with moderate compression in the vicinity of the support.

- Where changes in direction occurred, not one case was observed where all benches through the curve were uniformly compressed. Spans existed where one or two benches showed little evidence of compression, and so carried little pipe weight. This caused the benches either side to be severely compressed. Potential causes for this include:
  - Bench heights not uniform from one to the next
  - Bench heights not uniform along its own length, therefore pipe curvature not matching trench curvature will rest on different parts of bench, not always centered.
- As these same potential causes can lead to problems in the straight sections, whereas none existed that were so obvious, other potential causes are more likely responsible for the problems. More likely causes include:
  - Problems in matching the bend orientation to the ditch profile, and,
  - Problems in making tie-in welds.
- Similar difficulties existed at sag-bends and over-bends, where again not one case showed adjacent benches were uniformly loaded. Problems here were more severe than for changes in horizontal direction, as spans of three benches were evident, as was nearly complete crushing of the bench preceding this span. Again excluding causes shared for straight runs, likely causes include:
  - Pipe elevation change not matching trench elevation change,
  - Problems in making tie-in welds.
- In several instances, the pipe had to be raised up in sections that involved turns and elevation changes. It clearly shows (from the photographs) how the foam is unable to handle the pipe load if spans exist. This is pipe weight alone, BEFORE it is bedded, or backfilled, or water is introduced into pipe for hydrostatic testing.
- In one section coming over a hilltop, the pipe was not centered properly and a section of trench wall was not flush (had a slight protrusion) causing pipe to initially get hung up. In this section, foam was sprayed about a third of the way up wall to help with abrasion in a narrow section. Pipe hit at top and scraped on the way down. By the time it got to foam on sidewall it was centered. Foam in this type of situation should be sprayed ALL the way up the side of trench wall.

Additional Observations for Lowering-In

- Contractor opinion was that the foam benches were much quicker and less manpower intensive than more traditional sandbag method.
- The bench crew was found to be much faster than pipe could be lowered in, as this crew was miles ahead of the lowering-in operation.
- On spreads with significant hills and valleys, causing pipe to be strung and joined into many sections, the rather tedious process of tie-in welds appeared to dictate construction progress, with other issues apparently secondary drivers for completion of the spread.

Bedding and Padding Operation

- Three Ozzie padders were on-site, with a larger 300 model working in front of smaller 200 models. A double tandem scheme was common, with the third smaller padder available as backup for double tandem use, or for use in a triple tandem, or for dealing with tie-ins and other specialty areas. Each Ozzie had a single screen with a clear pitch passing one-inch aggregate per company specifications.

- See discussion of the Ozzie padder presented in the section on Market Link – Ozzie Spread for details of the operation and overall strengths and weaknesses of this padder, which apply equally here, and are reinforced as noted by observations specific to this spread.
- Extremes of pipe height over trench floor ranged from ~4 inches up to ~16 inches. Randomly chosen measurement sites indicated heights of 10, 8, 9, 12 and 7 inches.
- Size of the ditch relative to pipe was varied depending on type of soil and whether a turn was involved. Straight sections and areas through soft rock made by a "wheel" hoe trenching machine produced a fairly consistent width of 4 feet, which satisfied required minimum width of twelve inches greater than outside diameter of the pipe. A few short straight sections were apparently done by a backhoe and were about five feet across. Areas through turns and areas that were greater shot were much wider than this. Often the width at the top of the ditch was many times the diameter of the line pipe.
- The rate of progress varied relative to spoil and trench width and depth. For example, 1 hour and 15 minutes was taken to cover a 0.2 mile long stretch through a wide turn. In contrast, the same amount of time was needed to cover a 0.6 mile long straight stretch using one padder along ditch that was consistently four feet wide. Another similar stretch of 0.9 miles took 4 hours to complete.
- Where the three Ozzie padders worked in triple tandem, three bedding and padding passes could be accomplished in the time required for one, without the need to backtrack to affect the required coverage. Because the spoil pile created by machine ditching was almost all fines, there was no problem in fines supply through these areas. At times, the rear padder would back up a bit to cover a particular section that the pipe was higher off the trench floor or where the spoil was heavy in larger rock content, necessitating more frequent passes to develop adequate bedding and padding cover.
- In observing extent of fill once both sides of the pipe were padded, coverage looked complete, as the fill extracted from the spoil was fine enough to flow in and leave no observable voids.
- The depth of padding above the pipe averaged in the range of 12 to 18 inches.
- Padding material was obtained with a total of four samples, with the laboratory analysis included in Appendix D.
- Because the padding sequence involved all vehicles working linearly in a tight formation, no jeeping was possible as the pipe was fully covered in one pass, without access to areas available during start-stop cycles, or the period where the padder was repositioned for a second or third pass.

Additional Observations for Bedding and Padding

- During stretches where there were large rocks present in spoil and the spoil height was large, quite large rocks were occasionally knocked onto the pipe by the action of the padders. While the crew included laborers working along the ditch to intercept such rocks and thereby limit damage to the pipe, from time to time the rocks were too large to be stopped by the two-man shovel crew assigned this task. In such cases, the string of padders would stop and the assisting crew would patch the pipe with a thick application of two-part epoxy, covered by a tape-over, so bedding and padding could resume without concern for the cure time or the possibility padding material would move the patch or

adhere to it when they resumed. At least five such patching operations were observed in a day-long shift.

- At one point, a section that was covered with at least 12" of padding was hit by a large rock that rolled down the spoil pile. The cover displaced somewhat, but this large and heavy rock did not come close to contacting the line pipe's surface.
- In severe to extreme rock conditions, as occurred with shot rock, the padders were supplied by bulldozers that roached the windrow to supply adequate padding material.
- One short ring of pipe discarded from a tie-in provided the opportunity to assess the sensitivity of the brown-coat FBE to contact with rock. While not scientific, these ad hoc experiments using small rocks located in the right-of-way provide insight into the resistance of this coating to impact and scraping. The results of these impacts and scrapes showed this coating to be quite resistant to damage, at least at the moderate daytime temperatures of southern Nevada during February when it was in the high 60s (°F). More formal evaluation of coating damage resistance under parametric contact conditions would develop a quantitative understanding of what contact conditions are problematic, and facilitate developing value-based (performance) specifications to maximize safety in concert with productivity.

Backfill Operations

- Immediately following the padders, an auger dozer and two bulldozers performed the backfill operation. From the previous additional observation stating the large rock falling on the padding, I believe the backfilling procedure would not be capable of having larger rocks contacting or coming into close contact with the pipe.
- A "paddle" hoe was behind the backfill operation pulling dirt from the original spoil for subsequent leveling at a later time.
- Inspector was present for backfill operation.

Spread 8

This involved 36-inch diameter line pipe with 0.429-inch wall and factory-applied brown-coat FBE. This pipe was laid in a largely machine ditched trench, although some short sections involved shot rock.

Equipment (padding operation – several locations noted)

- Four Ozzie padders – two model 200's, two model 300's
- Two Outlaw padders
- Two bulldozers (backfill and roaching)
- Approximately 16 people involved in this aspect of operation

Equipment (lowering in)

- Four side booms

Equipment (other)

- One paddle hoe (moved backfill for leveling later by bulldozers)
- Numerous small water trucks (required for dust control)

- Two foam trucks – crew of 3, technician (company), foamer and driver (both contract employees), and Peter Ellis (Company Operations Manager)

Inspectors

- There were several inspectors present at padding operation – but unable to track and identify the exact number.
- One FERC Representative and one Enviromental inspector (that were readily identifiable through casual observations).
- Green hat biology monitors focused on ground turtles and their habitat in areas where heavy equipment was operating and walking the right of way between operations.

Supports (benches)

- See discussion for Spread 7

Additional Observations for Supports

- A couple of sections used dirt as the material for the benches. When an inquiry was made into this, the reply from Peter Ellis indicated an agreement was reached to allow this because the site boss did not want to lay anybody off, so a make-work job involving benches was created. Williams Pipeline indicated the dirt benches comprised approximately 15 percent of the total, presumably over the length of the spread.

Breakers

- Like the benches, breakers were made using sprayed-in place polyurethane foam.
- These were approximately one foot across at the top tapering out to approximately two feet at their base.
- Several breakers were observed with vertical and horizontal splits in the top section (photographed). While one inspector mentioned the Pedero personnel would make needed repairs, this was never observed.
- Pedero's website provides reference information and photographs typical of their supports and breakers. Their photographs showed tightly grouped breakers, which are more closely spaced than breakers installed at this site. However, ditch stabilization needed depends on many factors, such that direct comment on this aspect absent more detail is inappropriate.

Observations of lowering-in with relation to benches

- Comments for spread 7 apply here

Additional Observations on Supports

- There were some benches that seemed less robust as compared to those found in Spread 7, some of which did not run the full width of the ditch. While this looks bad, such is the case for pre-formed foam benches, and it is only problematic when the bench fails to support the pipe.

Bedding and Padding Operations

- Notes for Spread 7 apply here, with the following differences.
- Four Ozzie padders were used, with two 300 models and two 200 models involved. These padders tended to work independently, which required each padder to make several passes through roached spoil to attain the required bedding and padding cover.

The 200 model Ozzie tended to need three passes to achieve this. When a 300-model padder worked in tandem following a 200-model, the number of passes was reduced to two (i.e., one combined double pass).

- Where the 200-model padder was used independently, the first two passes impacted the pipe, first filling first one side over the crown and then the second side. The third pass supply cover across the full width of the pipe, with cover depths ranging from 18 to 24 inches.
- See discussion of the Ozzie padder presented in the section on Market Link – Ozzie Spread for details of the operation and overall strengths and weaknesses of this padder, which apply equally here, and are reinforced as noted by observations specific to this spread.
- Limited straight runs where ditched by backhoe were up to six feet across. In general, ditches in the vicinity of turns and areas involving shot rock were wider as compared to Spread 7.
- Forward progress on this spread was difficult to assess, as the several padders on this spread generally worked independent of each other. Accordingly, total forward progress was assessed by considering the padding accomplished by all four padders, which was estimated at about four miles over a three-day period for four padders, giving about a mile per 10-hour shift per padder.
- Padding material typical of that involved was obtained for three samples, with the laboratory report included in Appendix D.
- Because the padding technique involved a start-stop cycle where padders were repositioned for a second or third pass, it was possible to enter the ditch to jeep on two occasions. This was done by driving a four foot copper rod into the ground above the trench. A grounding wire from the portable jeep was connected to this and then thrown into the trenching location. Jeeping was done by climbing down a breaker and then walking the ditch. The first location involved a length of about 32 feet, which comprised the length of the grounding wire in both directions from copper rod. One coating nick exposing metal was found at approximately the 11 o'clock position, which was about ¼ inch in diameter. This large chip was likely due to larger rock that rolled down the spoil pipe that was not repaired, as no evidence of similar features were found along the 32 ft measured. The second stretch jeeped was approximately 100' in length, in a process aided by a top-side laborer that removing and reset the copper rod over this length of pipe. This jeeping failed to indicate nicks in the coating over this stretch. In both cases, this jeeping reflects steady-state operation.

Additional Observations of Bedding and Padding

- Two Outlaw padders were also used as bedding and padding in this spread. These were used specifically for runs involving a very steep grade and at tie-ins that had been bypassed by the Ozzie padders. Based on limited operations and crew comments, these machines appear to be slower than an Ozzie mainly because of their loading design. A bulldozer that roached spoil supported these padders, whose use involved a crew of four. (One Outlaw was broken-down during our time on site, which limited observations.)
- Cover achieved by the Outlaw ranged in 18-24" in depth.

- As was observed for Market Link, the observations indicated operator skill or technique is important for the Ozzie padder, as the observations here indicated the only time the spoil is directly hitting the pipe is during startup. It was noted that the operator works the spoil to fill the ditch at startup, after which spoil flows out across the top of the pipe then begins to proceed forward along the pipe-string. In this approach, spoil coming off the conveyor only hits the pipe during the initial fill, with operation later dropping fill material onto already existing fill that then flows out over the pipe. This provides a couple of inches of fill cushion that can cushion the fall of the 1-inch or smaller aggregate used, and limit damage to the coating.
- At one time, a rock approximately nine inches across fell onto shallow cover on pipe. The person walking alongside the padder went in and pushed it to the side, without visual inspection. Such behavior likely reflects experience that damage is not typically experienced for the cover present and the size rock involved, as other similar scenarios on Spread 7 that led to small chips and coating repair tended to occur with contact to unpadded or sparsely padded pipe. In contrast to Spread 7, for this spread the two-part epoxy patching used on Spread 7 was never observed, which suggests the quality of the final product is dependent on the crew as well as the equipment used to bed and pad the pipe.

Backfill Operations

- There were long stretches of padding done without any backfilling being done. When observed, it involved one bulldozer pushing in backfill to restore the grade.
- A “paddle” hoe was present for later leveling purposes but this observation was not witnessed in real time.
- Not sure if there was an inspector present for backfill operation.

Spread 9

Work finished on this spread in the week before our visit. Its topography and geography looked similar to Spread 10.

Spread 10

This involved 36-inch diameter line pipe with 0.429-inch wall and factory-applied brown-coat FBE. This pipe was laid in a trench dug either by a ditching machine or a backhoe through relatively soft sandy soil.

- This spread was flat for most of its distance and the soil contents were fine akin to sand.
- No padders were apparent, although the crew indicated there might have been one somewhere on this spread.
- There was no padding evident. The fill operation was completed by a bulldozer that moved fine spoil back into the trench.
- No benches of any kind were used here, the pipe was just laid in the trench although they did water compact the floor of the trench.
- Some stretches of trench were cut out using the “wheel” hoe (trenching machine), while other sections used a backhoe.

- The trenches were about 5' wide by 8' deep where the "wheel" hoe was used and wider when a backhoe was used.

Lessons Learned for Subsequent Visits

- When booking hotels for different spreads, getting one near where the actual work is being done on the spread versus where their offices are would significantly cut down on travel time and allow more time to be spent at the site itself.
- Some sort of compact/collapsible ladder would greatly increase ability to enter the trenches for jeeping tests. This allows quick/safe entry and exit and the ability move copper rod for longer jeeping runs.
- Acquire a longer grounding wire for jeep to increase distance of jeeping before having to replace copper rod.
- Bring a broom to quickly sweep off spoil from top of pipe to alleviate using hands/jeep paddle to remove dirt.
- Research applicable regulations for entering a trench to aid in ability to conduct tests.
- If spoil is kept wet by water trucks, compaction test is unnecessary.
- Voice recorder would increase frequency and detail of notes taken in field versus journal
- Ground markers of some sort to more accurately mark locations for distance covered by padders during a time period (hours/day, etc.). If the terrain is flat and free of landmarks, once the equipment is moved and pipe has been backfilled it can be difficult to relocate the exact stop-start locations, especially several days later.

Site Three – Patriot (Duke)

This project involved 24-inch diameter line pipe with wall thickness of 0.429 inch covered by tapecoat.

Equipment (padding operation)

- One Dynapad padder
- Two backhoes (both as padders and/or as backfill)
- One bulldozer
- Nine people involved in this aspect of operation
  - Two padding/backfill inspectors
  - One operator on Dynapad
  - One operator each for backhoes
  - One operator for bulldozer
  - One Dynapad padding assistant walking with equipment
  - One laborer per backhoe

Equipment (lowering in)

- Four side-booms (three shown, one holding up pipe at tie-in)
- One long sandbag truck (benches) – driver, 4 laborers (two on truck, two in trench) and foreman. They were a bit ahead of lowering in crew
- One Bulldozer

- One Marachi – halftrack vehicle with supplementary sandbags, ladders, miscellaneous equipment etc.

Equipment (other)

- One long sandbag truck – driver, 4-6 laborers and foreman (breakers)
- One metal skid for skids (dragged by a bulldozer)
- One bucket-type hoe, one clamshell hoe (dredging trench in front of lowering-in and behind jeepers and coating crew)

Inspectors

- Two for padding and backfill operations

Supports (benches)

- The typical number of sandbags varied from support to support, ranging from three to six in the sandy soil areas but predominantly three were used. Higher numbers of sandbags was used in instances where rises, sags, and turns were prevalent to accommodate pipe bends not exactly following the trench elevation contours or radius of turn and in the stretches containing rocky soil. Also, road tie-ins used an increased number of sandbags.
- The center-to-center distances varied widely with the terrain. One particular stretch yielded center-to-center distances of 10.5, 9, 17.5, 17, 15, 30, 6, and 20 feet. Only in very rocky and hilly sections were they relatively consistent, averaging six to ten feet. The specifications called for sandbag spacing to be approximately fifteen feet apart.
- Foreman was unaware of the cost of the sandbags.

Additional Observations for Supports

- One truck was positioned ahead of the lowering-in crew that was busy setting the sandbags for the benches. The first two days on site involved terrain that was sandy and rocky in stretches. When the soil was consisting mostly of fines, a few sandbags were separated by larger distances, while in other places the pipe simply laid on the trench floor. In the rocky stretches, the sandbag count and frequency increased to match the terrain.
- Differences in terrain led to apparently inconsistent arrangement of the sandbags. In some cases they were laid in what looked like a hasty manner. Where three or fewer sandbags were used, their use seemed less functional, as occasionally they did not keep the pipe of off the trench floor. However, as just noted this tended to occur where rock was absent, and so was not consequential. No attempt by the padding crew was made to adjust any pipe supports that otherwise might have not appeared sufficient.

Breakers

- The breakers at this spread were constructed using sandbags.
- The typical number of sandbags required for a normal sized breaker is approximately 225. The foreman stated that it would take approximately 30 minutes for a crew of four to construct this, which seems a viable estimate. The largest breaker observed contained over 900 sandbags.
- Typical breaker dimensions were 15 inches wide, stopping about one foot below the top of the trench.
- The breakers appeared to be well constructed and uniform.

Observations of lowering-in with relation to benches

- Lowering-in involved four side booms with at least two laborers or lead hands walking along side. The person walking in the back was responsible for keeping the pipe either centered in the trench or on the benches if present. The section where lowering-in was occurring typically involved a flat rock-free trench where the pipe was laid directly on the trench floor, with no sandbags involved as is usual for such trench bottoms.
- This particular section of the spread was fully strung and the pipe joints welded, except for road tie-ins, as compared to other spreads where the jointed pipe was much more segmented and so involved more tie-ins.
- Sandbag footprints varied greatly. The sandbags themselves were in the 10 by 15 inch range, with a footprint consisting of a 10 inches by 30 inches.
- There were several instances of the pipe not resting on the benches with the greatest span being five benches bypassed with no contact, as evident in the next photograph. A significant portion of the pipe observed contained few to no sandbags due to the soil content consisting mostly of fine material with little to no rocks present. However, it can be anticipated that elasticity in the pipe string and compression in the benches will facilitate eventual settling onto the bedding.

Additional Observations for Lowering-In

- There was an instance where a side-boom slipped off the edge of an area of stepped ditch, which knocked the pipe off of the skids and into the trench. Approximately 1500 feet went into the trench. When the pipe was raised out and inspected, there were two dents requiring cutouts and numerous divots in the coating that also required repairs.

Observations of Bedding and Padding Operations

- The Dynapad was used throughout
- See discussion of Dynapad padder presented in the section on Market Link – Dynapad Spread for details of the operation and overall strengths and weaknesses of this padder, which apply equally here, and are reinforced as noted by observations specific to this spread.
- As for Market Link, Dynapad provided a layer of fines about 12 inches deep on average, followed by a small rock layer and thereafter larger rocks.
- In most trench areas where the soil was fine without rock content, the pipe was laid directly on the trench floor. Occasionally in these types of area, stacks of three sandbags were used as supports, being spaced along the pipe-string at quite large distances. These appeared to have little to no impact on the clearance between the trench and the pipe, as 1 to 2 inch spacing or more was found in some places where at other sites the pipe rested on the ditch bottom.
- In rocky areas where more sandbags were used and spaced more closely together, the supports developed the required offset, as clearances there measured at random sites ranged from 22 inches to as little as four inches, but more typically were in excess of 10 inches, while the specifications targeted eight inches.
- The size of the trench relative to the pipe was measured in several sites. These measurements indicated trench widths from the order of four feet up to seven feet, with depths from seven to more than 9 feet. Trench width easily met the required minimum

width of twelve inches greater than the outside diameter of the pipe, with eighteen inches required when there is rock in the ditch or water crossings (creeks, streams, rivers) are involved. Likewise, the depth easily met the specified minimum that required a minimum cover of thirty-six inches for stretches not involving railroads, highways, water crossings etc. This equates to a minimum depth (clearance + pipe diameter + minimum cover) of 5feet- 8 inches, whereas the depth as measured was typically greater than seven feet.

- The nature of the ditch at the time of observation involved short stretches where rock was present interspersed in long stretches where few to no rock was present. The padder was used of the short rocky stretches, while the remainder was padded with backhoes from the spoil pile.
- Two short rocky stretches were timed with the Dynapad covering 175 feet in 30 minutes for one stretch and 217 feet in 20 minutes for the second stretch. The combination of the fines, two layers of small rock and spoil spilling over the back of the hopper as it is being loaded from the backhoe affected coverage of at least two feet with upwards of three feet.
- In observing the extent of the fill under the pipe, the material flowed freely underneath and filled the area underneath with no discernable voids.
- The padding operation involved one Dynapad padder, two backhoes and one bulldozer with a total of seven personnel (equipment operators, one inspector, two laborers). There was another padder on site, but it was relegated to mopping of tie-ins and other spot areas.
- Because backfill via backhoe immediately followed the bedding and padding process, there was no start-stop cycle to admit jeeping the pipe for nicks in the coating. But as noted previously, the design of this machine layers fines adjacent the pipe with increasingly larger material away from the pipe, which limits the chance of rock contact and so virtually precludes rock damage.
- Padding material was obtained with one sample from an area consistent with most in the area of observation. The laboratory soils report is in Appendix D.

Additional Observations for Bedding and Padding

- The depth of the padding coupled with the double layering of different sized rocks was sufficient to keep large rocks coming off the back of the hopper and from backfill operations from impacting the pipe.
- The operator for the Dynapad stated that on a good day with the backhoe operator keeping up he was capable of doing about 9000’ over flat stretches. However, this estimate cannot be verified in reference to the data gathered from this site, which at best indicated 651 feet per hour or about 6510 feet in a 10-hour long shift.
- Where the spoil is wet, the same problems evident in limited observations for Market Link were again apparent. There was some evidence of blockage that slowed progress, and the fines were prone to clumping that becomes evident from the start of processing the wet spoil. The design of the hopper area on a Dynapad also appeared susceptible to clogged from roots and other debris in the spoil pile. If roots were left to build up enough, it was remarked that they would need to be burned out.
- In some places (sags), standing water was not pumped out.

Backfill Operations

- The backfill process was accomplished with a backhoe with fill material obtained predominantly from the spoil pile.
- The padding appeared to be of sufficient depth that any large rocks from the backfill would not come in contact with the pipe.
- A bulldozer was used to top-off the trench after the backhoe was finished.
- An inspector was present for all backfill operations.

Additional Observations for Backfilling

- There were times especially near tie-in areas where a backhoe was used for padding when the spoil contained significant rock. I noticed on several occasions where large rocks fell on the pipe in these instances. As such, overall coating quality is controlled by much more than the bedding and padding machine used over most of the job.
- The bucket from the backhoe was used occasionally for compaction after the backfill was deposited.

Site Four – Cardinal (Marathon)

This project involved 14-inch diameter line pipe whose wall was 0.25-inch thick, with a mill-applied green dura-bond thin-film FBE coating. The ditching was done by backhoe.

Equipment (padding operation)

- One Ozzie padder – model 200
- Two backhoes (one backfill, one roaching)
- One bulldozer
- Nine people were involved in this aspect of operation
  - One padding inspector
  - Two operators on Ozzie (one local, one Canadian District Manager learning operation of equipment)
  - One operator each for backhoes and bulldozer
  - One Ozzie padding assistant walking with equipment
  - Three laborers

Equipment (lowering in)

- Three side booms

Equipment (other)

- One foam truck – crew of three, technician, foamer and driver (OJS Company, which is Offshore Joint Services)
- One skid truck
- One bulldozer

Inspectors

- One inspector was present for padding and backfill operations.

Supports (benches)

- Polyurethane foam was initially used at this site but was discontinued before my arrival. Its use was stopped subject to procedural requirements.
- Sandbags were used while I was there but was told that they would probably be going back to foam benches at a later point.
- The typical number of sandbags per support was five, ranging from four to seven. In some cases, more sandbags were used in instances where rises and sags were prevalent, to accommodate pipe bends not exactly following the trench elevation contours. Also, a greater number of sandbags were used at all tie-in locations due to a deeper trench being dug at these locations.
- Sandbag count along a typical stretch indicated the number involved was 5, 5, 5, 7, 7, 5, 6, 5 and finally 5 again.
- Typical configuration of a five sandbag arrangement was two abreast; two abreast above that and the fifth sandbag straddling center position on top.
- The sandbags were bought from a local company at a $1.25 a piece. Trucks would drive the right-of-way depositing sandbags for benches, which per comment on site was to occur every twenty feet. The lowering in crew would place the sand bags as they proceeded. Extra bags were to be available where needed. I did not witness this, but estimate from prior observations at other sites two people were placing bags in trenches for supports.
- In one stretch, the distances between successive sandbag placements were as follows: 18.5’, 16’, 19’, 18.5’, 20.5’, 12’, 19.5’ and 16’. Another shorter stretch showed spacing at 16.5’, 17.5’ and 18.75’.

Additional Observations for Supports

- It was stated that the placement of the sandbag supports was to be every 20’. The measurements indicated that the majority of the distances came in under this distance. This in turn will decrease the load per bench and help decrease the possibility of ovalization or denting of the pipe.

Breakers

- Open cell polyurethane foam was used, which allows the passage of water, was used for the breakers. The company providing this service was OJS.
- Technician stated that foam temperature reached 135 degrees during curing. The technician was unable to provide density or compressive capacity.
- Typical breaker dimensions were 12 inches wide and 4 feet to 4.5 feet high. They were spaced using the following company specifications: for slopes at 5-15 degrees space at 300 feet apart, from 15-30 degrees space at 200 feet apart and over 30 degrees space at 100 feet.

Additional Observations on Supports

- There was no evidence of splitting in the breakers was seen once or twice at Kern River. The one split observed on the Cardinal spreads was caused by the raising of the pipe to add additional sandbags at one location.

Lowering-in with relation to benches

- The lowering-in was done well ahead of the padding crew so this could not be easily observed given the project's focus was bedding and padding. It was however apparent that the pipe-strings that were jointed were quite segmented, driven apparently by the topography and routing, which led to many rises and sags, some of which were quite steep. The tie-ins at roads crossed (there were many in the stretch I attended) were not completed. There were also many portions along the route that were not yet welded. .
- A typical sandbag footprint was the order of 15 inches by 36 inches.
- A rough estimate indicates that at least 95% of the pipe was properly seated on the benches. Only a few instances were observed where there was space between support and pipe and it was never more than one bench in span. However, this is likely to change as tie-in welds are completed. The inspector indicated that on several occasions he had the pipe lifted to adjust bench height, although such permits only coarse adjustments if it was done. Accordingly, the absence of tie-in welds is the most likely reason for this high frequency of well-seated pipe.

Bedding and Padding Operations

- The padding operation involved one Ozzie 200 model padder, two backhoes and one bulldozer accompanied by nine personnel. There was another padder on site but it was relegated to mopping up of tie-ins and other spot areas.
- The Ozzie's screen pitch for this job was two inches by two inches.
- A majority of the time, the fill material being introduced from the padder into the trench was not impacting the pipe. The flow was directed by the operator to hit in between the pipe and the trench wall. On subsequent passes for the same side of the pipe, the fill material would spill over the top of the pipe and then the other side of the pipe would be padded. The final passes would meet the required cover over the pipe.
- Along a joint of pipe, clearance heights from bottom of pipe to trench floor were 9, 11, 13, 18, 12, 9 and 11 inches, while random locations showed clearance heights of 10, 12, 10, 9 and 14 inches. The largest clearance measured was 19 inches, although inaccessible locations such as near tie-ins showed even larger clearance.
- The typical ditch width was 5 feet wide, with the narrowest being 3 feet-8 inches. The typical ditch depth was 6 feet, with slightly deeper instances measured. The specifications for a 14 inch diameter pipeline require a minimum trench width of 30 inches and a minimum trench depth of 56 inches (clearance + pipe diameter + minimum cover) in areas other than industrial, commercial, residential, crossing of inland bodies of water, and public roads and railroad drainage ditches.
- The rate of progress for the Ozzie varied widely depending on the fill circumstances encountered. For example, a one-day shift on one occasion covered about 600 to 700 feet, while this same period on another day covered about 2400 feet. Often the terrain was hilly and muddy, which hampered forward progress.
- The number of passes required to achieve the required bedding and padding cover varied as is expected. A minimum of three was required to obtain the proper cover, with as many as six required in the worst case. The high number of machine passes was necessary due to the extent of mud prevalent at the site. The wet and clumped dirt/mud coated the screen and did not pass easily through the screen. The required cover was 6

inches, with the padding applied easily exceeding this requirement. The cover thickness ranged from 8 to 12 inches typically, and sometimes was even deeper.

- The extent of the fill under the pipe was as for cases where the spoil was dry, evidently because the fill material that easily passed the screen had properties comparable to cases where all fill material was dry. The fill flowed freely below the pipe and filled the area underneath with no discernable voids.
- While the majority of the time, the fill material introduced from the padder was directed by the operator to hit in between the pipe and the trench wall, there were instances of the padding material landing on the crown of the pipe. Such occurred for a short stretches as the operator redirected the flow. When the operator was traveling over a double-stepped dich shoulder, which was necessitated due to the contours of the hill and the direction of pipe travel, the likelihood of hitting the pipe was much more prevalent. Jeeping was done whenever possible for such scenarios, but these opportunities were constrained by safe entry to the trench. Entry had to be performed at the foam breakers due to trench depth. Also, if breaker was too far from point of interest, too little time was available to get into the ditch, perform the jeeping, and then get out without inhibiting padder progress. About 400 of such padding operations were jeeped, with only one instance chipped coating identified. This chip was found where fill material from a two inch square clear screen pitch fell directly onto the crown of the pipe. Small regions of chipped coating are easily dealt with by the cathodic protection system. Nevertheless, such chips reflect reduced coating quality as compared to a pipe-string installed free of such features.
- Padding material was obtained for three samples, the laboratory report for which is reported in Appendix D.

Additional Observations for Bedding and Padding

- One of the main factors controlling progress for the Ozzie was the extreme muddiness. A second key factor was the fact that the right-of-way was only 50 feet wide, which allowed space for only the trench and one lane. This appeared to cause several problems:
  - If any equipment had to get in front of or behind someone else for any reason, everyone had to move out for the others to get in and then the procedure was reversed to get back to original orientation.
  - During the period observed, the Ozzie could not work the spoil pile so it was getting its padding supply from a backhoe roaching the adjacent right-of-way.
- The Ozzie, like any screen-based system, does not handle extreme muddiness very well. In addition to slowing progress, dealing with the mud required a twice per day cleaning that required 3 to 4 people and led to 1½ hours downtime twice per day. Mud was observed to buildup underneath the conveyor belt and chain to thickness up to about 5 inches, which was so compacted that its removal required it be chipped away with a shovel.
- One possible concern associated with any padding machine was occasionally evident where the cover was observed to take on the shape of the pipe, or form a crown over the centerline where the cover is deeper than on either side. Where the depth is minimal and measured over the centerline there is a change the flanks are not adequately covered. Moreover, there is a tendency for larger material placed over the cover during backfill to

fall toward the space between the pipe and ditch wall, possibly wedging into such areas, or enabling large rocks to be resting closer than desired to the pipe-string.

Backfill Operations

- The backfill process was accomplished with a backhoe drawing from the spoil pile when it could be reached, or from fill material lying on either side of the right-of-way.
- The padding appeared to be of sufficient depth to keep any large rocks entering the ditch during backfill from contacting the pipe when deposited by the backhoe.
- A bulldozer topped-off the trench after the backhoe was finished.
- An inspector was present for all backfill operations.

Additional Observations on Backfilling

- The bottom of the bucket on the backhoe was used for compaction, which could cause movement of larger rocks.
- As is the case in general, where the ditch is unstable large rocks deposited during the backfill process could move through the cover and padding possibly negating their function.

Industry Experience and Commentary

In addition to discussions with construction and operating company personnel during the site visits, a meeting was hosted at Battelle with Mr. Carl Turnage of Ozzie, while discussions with Mr. Ed Klaymar of KNI were held at various locations typically associated with INGAA meetings or construction spreads. Discussions also were held with Mr. Jim Jackson and others of CRC-Evans, and with various pipeline company personnel via telephone interview and Email dialog. Aside from the comments made by Mr. Jim Jackson of CRC-Evans, the most significant of these reflect dialog with Mr. Henry Yamauchi representing the experience of West Coast Pipeline.

Unfortunately, such discussions often reflect the commercial interests where equipment suppliers are involved, or specific experience of an individual that might be dated or otherwise biased by the characteristics of a given construction job when dealing with individuals. Nevertheless, some valuable insight was developed.

Mr. Jim Jackson – CRC-Evans

For example, when asked how the productivity of the various padding machines Mr. Jackson noted that none of the padding machines work well in wet material, especially not clay. This observation verifies the rather limited experience developed in this project. He also noted that for one job in the California desert where the spoil consisted of river rock and dry material rich in fines, he noted they were able to pad over 8,000 feet of pipe in less than seven hours. He further noted favorable comparison for the Ozzie padder, stating it was a very high production machine. Such rates outstrip anything observed in this project, although they provide credibility to upper bound rates noted for Dynapad at 9000 feet per day. What is clear from this is that productivity is strongly dependent on the fill conditions being bedded and padded.

When asked how pipelines were padded in the “old days” – Jim mentioned that they had their tricks; they would use the spoil in the ditch as a “ramp” to roll padding material down the slope toward the pipe. This way they would try not to directly impact the pipe with large rocks – the

success of this technique had a lot to do with the contractor performing the work. This remains the technique used by Ozzie's operators during startup, as they seek the richest area of fines in the spoil pile and direct that fill at the side of the ditch opposite the padder until it fills. Thereafter, they apply material directed onto the spillover from the first side padded or into the still unfilled space between the pipe and other ditch wall. Once the ditch is initially filled, they direct material onto the already covered pipe with forward motion of the excess cover rolling down the ramp created by the angle of repose of the fill material. Jim also provided some interesting history and related discussion, including the photo shown earlier in Figure 1a.

Mr. Carl Turnage – Ozzie Padder

The meeting with Carl Turnage was also productive, as it included some history and an overview of the construction process, which was supported by videos that included reference to foam benches and other aspects considered by some to be new technology. Carl addressed issues as perceived by Ozzie, from productivity through new technology.

A key theme of Carl's was construction productivity in reference to meeting or beating the time to bring the pipeline into operation. Carl noted that bedding and padding productivity was an important factor in this timeline, but also emphasized other aspects of construction such as the ditching technique, comparing blasting to machine ditching. Carl also spoke briefly about contract requirements and how they and subcontract provisions can effect how a job is approached.

Carl identified tie-in welds as controlling construction productivity for spreads with many crossings and hills and valleys that force jointing many segments of pipeline that then must be tied together, noting the tie-in weld was the limiting factor. This observation reinforces the same conclusion drawn first for this project while observing the several hours dedicated to this process on Kern River Spread 7, where the entire spread effectively came to a halt at times while tie-ins were completed. This means that while productivity and costs related to bedding and padding are important, they are not controlling and might be secondary to other more significant drivers, depending on the spread profile and routing. Evidence of this can be seen for Kern River Spread 7, where up to three Ozzies ran in tandem (leading to three times the cost) to achieve productivity, which otherwise was largely suspended when a tie-in was needed.

When Carl narrowed consideration of productivity to bedding and padding, he noted the amount of fines available as the primary driver, which underscores the presence of supporting equipment and personnel to roach for spoil where Ozzie padders were used.

In reference to new and emerging technology Carl mentioned combination crusher/padding machines, but noted they are currently very slow – a clear drawback given his emphasis on productivity. He mentioned the Grub crusher (CRC-Evans/Laurini) that runs along the bottom of as a viable alternative to bedding. He noted the machine ditch works well, using a hammer type system to crush rocks in the bottom of the ditch. He further stated that "the industry is going toward bottom padding in the ditch before laying down the pipeline so that it will better conform to the shape of the ditch", indicating that "Ozzie will be running a machine laying bottom padding, followed by a machine behind the stringing operation to add the additional padding".

Carl went on to note that Ozzie is looking into the use of a bucket-type padder that has an auger device in the bottom of the bucket to break up mud/clay material. They also are looking at using a crushing machine with their padding machine to make better use of the spoil pile. His

comment reflects the diminishing returns as several passes are made over the same spoil that were identified in reference to the Ozzie machine, beginning with the Market Link project. He noted that combining a crusher with the padder will enhance the amount of fines, and minimize the need to have to haul away the large rocks upon completion of the padding job. However, again he pointed to the downside currently is reduced productivity.

He also commented on rock shield technology, specifically in reference to polymer (fiberglass or polyurethane) coatings, which variously includes fibrous cushioning materials. His comments reflected a competitor's position, as they indicated large rocks can still damage pipeline, and also noted this technology tends to shield the pipeline from CP. However, these views tend to be shared by the industry, as there was little evidence of pipe-applied polymers used for rock protection in the projects visited. Moreover, personnel from at least two pipeline operating companies shared these same concerns. Polymer foam breakers as well as foam pillows are also likely to shield the pipeline from CP. In spite of this, such technology was developed and first used in Canada where near-neutral pH as well as high pH stress-corrosion cracking is prevalent, without apparent concern.

In regard to benches and breakers, Carl warned that foam does get hot and if not properly mixed can get hot enough to burn the pipe. He also commented on denting the bottom of the pipe caused by sandbags, where the bags were not spaced or placed properly. These comments served to confirm project team observations, and comments made by others during the course of this project.

In closing, Carl commented that it costs anywhere from $2 to $4 per foot to perform the padding operation – with the cost depending on the number of tie-ins, terrain along the spread, timing; and other factors. He noted that Ozzie has padded 1,000s of miles with their machines, starting with the Iroquois Pipeline about 1988.

Mr. Ed Klaymar – KNI

Mr. Klaymar's primary focus in conversation is the same message evident in material he has written on behalf of KNI[(10)], which focuses on pipeline support, bedding and padding, and trench stability, along with the quality of the fill material deposited, aspects considered by KNI to comprise their layered backfill system. Key themes include the merits of layered backfill in reference to limited damage to the pipeline coating, and the stability of the ditch as affected via geotextile fabric deposited above the layered backfill, and the fact these can be installed at no added cost as compared to other bedding and padding construction practices. He also alludes to foam benches as an element of his construction system associated with the Dynapad bedding and padding machine. Because an objective of this project was to evaluate the layered backfill system, this section presents the discussions with KNI in conjunction with commentary on the system based on the data and observations of this project, and the technical literature to the extent it speaks to these topics.

In regard to pipe supports, material supplied by KNI indicates its new, patent pending, pipe support method overcomes the cost and quality disadvantages of the pipe support methods in current practice. According to their literature and site observations at the Market Link project, KNI's method uses foam benches designed to be strong enough to support the pipe after it has initially been lowered into the trench. It claims that as opposed to current methods the support benches are constructed to fail when the additional cumulative loading produced by complete

backfill and hydrostatic testing is applied. While this is possible, calculations that support this claim are absent, nor are tables provided that indicate design changes necessary to achieve this as a function of backfill density, product density, ditch depth, and pipe diameter and wall thickness. Analysis presented in Appendix E and related considerations noted there indicate the design compliance and related properties such as the time constant of the support material must depend on these parameters.

Achieving the behavior claimed requires uniform support for and loading on the benches, a feature that is unlikely given the variability in typical trenching for pipeline construction. While this variability can be offset if the benches are individually shimmed and uniformly supported by the ditch bottom in an unloaded state, such that they can develop uniform contact by the pipeline during and after lowering in, this will slow productivity significantly and has the potential to involve significant cost. More importantly, there was no evidence of such in evidence where these benches were in limited use on the Market Link project. The claims further note that pipelines installed according to this method will be supported by the padding material beneath the pipe, leading to full compaction, which is certainly the case if the installation achieves uniform support and compresses under the imposed loads. Whether uniform compaction greatly reduces the problem of padding wash-out as claimed could not be confirmed directly, as detailed controlled studies to evaluate this aspect could not be found in the open literature[6]. However, while the literature does not address this issue directly, soil mechanics texts do suggest that, when the soil is not fully compacted precluding the existence of pores and constrained on all directions, water ingress is possible. This implies that where water is present along the ditch bottom it could eventually permeate the once vertically compacted fines. On this basis, it is not clear that soil initially compacted in one dimension will remain resist washout when sufficient water is present.

It also is worth noting that the sprayed in-situ foam benches in use in Canada since the 1980s are from a practical perspective as likely capable of claims similar to those posed by KNI, particularly in reference to uniform bottom support. Moreover, as the size and shape of supports sprayed in-situ offers theoretically infinite adjustment, supports sprayed in-situ likely are more easily "aligned and shimmed" by spraying materials as needed as compared to precast blocks that do not match the ditch bottom and so must be shimmed from both sides. However, as the structural and failure response of any design built of viscoelastic, time-compliant material depends on the stress imposed[(42)], the design of such benches and the open- or closed-cell foam used must reflect backfill density, product density, ditch depth, and pipe diameter and wall thickness, and have a time constant consistent with the timeline for subsequent bedding and padding. Presently it is known that the Pedero products involve concern for at least some of these parameters, as the foam density among other parameters is dependent on the pipe dimensions and the product transported. However, no such data was made available by KNI following the Market Link visit, nor is such data evident in the KNI literature on their patent-pending benches. Finally, as the benches delivered to the Market Link project had fixed width, it is not apparent how variables such as differing fill density or ditch depth were to be addressed,

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[6] A limited GRI-funded study[(41)] was located that provides the potential to evaluate other aspects of KNI technology was found, however as yet the necessary follow-up to evaluate this work has not yet been initiated.

nor was their evidence they were design considerations through the foam design, as the benches bore no designation to discriminate this parameter.

The KNI literature also speaks to concerns involving settlement into the bedding, and related compaction. While a concern of this project, nothing could be found in the literature that directly quantified the relationship between the initial quality of pipeline support and its effect on future pipeline functionality. A related exception was anecdotal evidence of the effect of overly stiff and ill-placed sandbags in causing ovalization and denting. Significantly, sandbags made using the traditional burlap sack would only be as stiff as the burlap bag was strong, and its seams resistant to splitting. On this basis, one might conclude the use of modern stronger polymeric materials for bags, as has been observed, could lead to additional problems associated with ill-placed bags. For example, burlap bags might have split under the action of the weight of the water during long-term hydrostatic tests, or in-line inspection, making this a short-term concern and promoting settlement into the bedding. However, their stronger modern counterparts might survive retaining any local pipe distortion. In the same vein, the modern materials are not prone to deteriorate over time, as would burlap bags. This leads to the possibility that any ill-placed sandbags made of strong polymeric materials resistant to rot will continue to cause distortion of the pipe's cross-section and the pipe-string's profile, whereas the burlap bags would rot leading to eventual settlement into the bedding. As results to evaluate such aspects could not be found in the open literature, little can be said in regard to their possible significance over the long term.

The merits of layered backfill have been discussed with Mr. Klaymar in reference to limited damage to the pipeline coating achieved via layered backfill, which grades and places three tiers of fill material prior to backfilling. According to those discussions and their product literature, the three in-line screening stages of the Dynapad cover the pipe first with high quality padding material, after which a layer of small sized stone follows, which is followed by a third layer of larger sized stone. Their literature claims a much higher level of pipe protection than current padding and backfill methods and virtually eliminates construction created pipe and pipe coating damage. This claim, which is made in passionate terms in discussions with Mr. Klaymar, has been verified at all sites visited where Dynapad was used, with no evidence of damage evident in any case. Whether this finer-quality layered fill material affects the integrity and reliability of the pipeline as compared to other padders depends at least on operator skill and experience in regard to the Ozzie, the nature of the coating used in regard to its resistance to damage, and the presence of adequate and reliable CP. Corrosion that might ensue at such coating defects becomes a threat to integrity only where the CP is unreliable or inadequate, neither of which is a practical concern early in the life of a new pipeline. However, such chips can become a concern later in the life if, when, and where the CP system becomes unreliable or inadequate – both of which are regulatory issues.

Finally, KNI technology was discussed in reference to the stability of the ditch as affected via geotextile fabric deposited above the layered backfill. Discussions and their literature indicate that the Dynapad has been adapted to install this geotextile fabric between the padding material and the first layer of sized stone, which is claimed to stabilize the backfilled trench and the protective padding layer for the life of the pipeline. Whether or not this added layer of geotextile fabric functions as claimed could not be confirmed, as detailed controlled studies to evaluate its function could not be located in the literature[6]. Likewise, their literature claim that this low cost of the geotextile fabric will be more than offset by eliminating currently required construction

counter measures such as trench breakers also could not be evaluated as detailed controlled studies to evaluate its function could not be located in the literature[6].

According to KNI literature and related discussions, backfilled trenches require stabilization in reference to padding washout that occurs in one of two forms. One involves erosion along the trench as water flows where a gradient is present along the largely impervious conduit that is created by trenching and filled by the pipeline, the select fill materials nearby and the backfill above. Discussions with the industry personnel indicate this form of washout is known to the industry. Personal observations by the authors likewise validate this form of washout. The KNI literature asserts a second form of washout can occur if the padding material saturates with water sufficiently to cause a change-of-state. This scenario is quite plausible as it has analogs in nature. KNI asserts that where excess water accumulates and stagnates in the bottom of the trench, the padding material change state from a solid to a liquid (mud). While not included in the KNI literature, freeze thaw cycles that tend to move rocks toward the surface will also be active for rock that lie above the frost line, more so in areas and over depths where many such cycles are experienced annually.

As problems with flowing water are significant where there is a gradient to drive the flow, the industry has controlled flow by installing breakers across the full width and depth of the trench, which functions as a dam. But, while breakers limit flow and displacement of the fill material by erosion, they set up conditions that contain the moisture, such that where sufficient water is present to change the properties the second form of washout is plausible. When such conditions reach a depth that affects the fill material bridged above the pipeline, it is conceivable heavier rocks placed in the backfill could migrate toward the pipe-string or the trench floor. An indication of the practical significance of the change-of-state washout can be inferred in reference to the known buoyancy of natural-gas transmission pipelines. The buoyancy of natural gas pipelines is apparent as are known to rise through the soil of soft water soaked flats or other areas that make them buoyant unless retained by swamp-weights or the weight of a concrete coating. Consequently, the second form of padding wash-out – if a significant problem – should be evident on such systems through humping above these pipelines akin to the "speed-bumps" that occur in the soil of soft water soaked flats. As most operators don't generally report this problem, one can conclude that while plausible it has yet to become an industry issue.

While apparently not an industry-wide concern, the KNI literature asserts that the change-of-state wash-out is readily found immediately above trench breakers. This assertion has some credibility in that the KNI literature claims one (un-named) major transmission company has specified that French drain systems involving PVC pipe be installed on the trench floor immediately above trench breakers, with the water so collected drawn off through the breaker. It gains further credibility in that at least one company with pipelines through very hilly and mountainous country is experimenting with a method to control water between their breakers, as considered in regard to discussions with Mr. Henry Yamauchi reported subsequently.

The final aspect considered with KNI was future directions and developments involving bedding and padding, and related construction aspects. Mr. Klaymar noted that the high costs required to implement current construction specifications are driving the development of new generations of rock trenchers and pipe coatings. He noted the hope that either a rock trencher/crusher would be developed that could economically grind the rock into useful fill material, and/or new coatings could be developed that were more resistant to chipping and other rock damage, making issue of backfilled rocks moot. He also alluded to costs associated with maximum rock size restrictions

now being included in prescriptive company backfill specifications, stating that much cost is incurred in segregating and removing the oversized rocks from the right-of-way. Finally, he alluded to expensive trench breakers that are installed where the pipeline trench is excavated on hills, suggesting an alternative such as his geotextile fabric is needed to stabilize the ditch. While such an alternative would be welcomed, it is not clear how a thin but tough fabric could stop heavy rocks from sinking if indeed the properties of the mud had the viscosity of a liquid such as water.

Mr. Henry Yamauchi – WestCoast Pipeline

After a friendly exchange of greetings, Mr. Yamauchi outlined their current experiment with a drain system much like that alluded to in the KNI literature, although as yet the practice is still experimental. He stated "Recently, some pipe, 914 mm OD, was installed in shot rock, blasted ditch. The pipe was embedded in sand with minimum of 250 mm on bottom and 300 mm above the the pipe, followed by placement of non-woven geotextile fabric Nylex 4553 on the select sand padding, extending 150 mm up the sidewall of the ditch. Since we had previously experienced some padding losses, which could have contributed to pipe dents on bottom of pipe discovered by internal inspection tool, particularly in shot rock ditches, due to water migration into the soft ditch line, we decided to contain the sand-pad for this project by placement of geotextile fabric above the padding, followed by placement of excavated material over the geotextile fabric.

He continued, "We have previously used ditch blocks, with drainage lines to intercept and direct water out of the covered ditch. Depending on drainage pattern, this method worked satisfactorily but at a substantial cost. Installation of ditch blocks with drainage pipe costs approximately $8,000 Cdn. per set. Depending on drainage pattern and precipitation area, many ditch blocks with drainage lines are required to control water flow in the ditch line. A roll of geotextile fabric Nylex 4553, 15' wide by 300' roll costs about $500 Cdn. This would cover about 600 lineal feet of ditch."

As WestCoast pipelines operate through very hilly and mountainous country where change-of-state is most likely, his correspondence lends credibility to both mechanisms for washout noted in the KNI discussions. But in contrast to the KNI practice, the geotextile fabric used in this experiment lies above the padding and below the pipeline, a placement scenario much different than what can be achieved with the Dynapad machine where the fabric is placed above the padding.

Observations and Trends

This section begins with general observations. For present purposes, general observations reflect a recurrent consistent position or trend. This observation or opinion must be evident throughout the spreads visited, or in the comments from individuals whose observations or opinions became evident on the spread, or were sought in meetings and other forms of correspondence or phone dialog. Recurrent, consistent patterns comprise trends, the most significant of which are noted later in this section. Where limited data or observations exist, but the outcome is experience-proven and/or logical, the corresponding pattern is considered a trend. Finally, as head-to-head comparisons could not be made between the practices and equipment considered because of practical field constraints, no attempt is made to compare one against the other in this section.

Productivity

- Integral in-line loader and screen machines operate well in situations where the spoil contains rich to adequate fill material. They become less productive even when run in tandem as the spoil provides diminished fill material, as roaching for fill material can be tedious and such is not easily utilized.
- When dealing with spoil that contains very large rocks or debris such as roots, the stacked systems will likely lag the integral in-line machines – but where the spoil contains limited fill material and there is limited large rock and debris, the independently loaded stacked machine should outpace its integral in-line counterparts.
- Ditch width and height are important parameters, with width being most significant in regard to the fill material required in reference to the specified minimum parameters. Wide uncontrolled ditches limit productivity, and can become a controlling parameter in applications where limited fill material is available in the spoil.
- In applications involving rock that can be either shot or machine ditched, the balance of factors such as speed and cost in creating the ditch and spoil can be balanced or offset by the speed, cost, and construction convenience afforded by the controlled ditch size, the extensive and available rich spoil, and the ability to use the ditch as a reverse rock shield in conjunction with sprayed foam benches. Where it is "possible" to machine ditch the rock in lieu of blasting, all factors from productivity through economy and safety, etc., considered, subsequent construction is facilitated and productivity enhanced.
- Lighter and more portable vertically stacked machines appear more cost-effective where the run needing the padding equipment is short, in contrast to cases where the run is long and so justifies the large equipment and mobilization/demobilization costs.
- Lighter and more portable vertically stacked machines appear more practical and cost-effective for short looping or replacement jobs, and in rights-of-way that are narrow or involve space limitations for heavy equipment because of the presence of hot pipelines, or the location of the spoil.
- New technology is on the horizon that couples crushing with loading and bedding and padding, which as productivity issues are resolved will obviate the concern for rock.
- Construction productivity and decisions related to machine selection are controlled by more than the forward progress of the bedding and padding crew. Where construction involves many tie-ins because of routing or topography, the tie-in welds appear to be the rate controlling step.
- Where productivity is in balance with cost, particularly when Ozzie padders are used, equipment cost and cost related support for the padder, including roaching to enhance the spoil, appear to be secondary to productivity.

Crews and Equipment

- Crews and that amount of equipment involved with and supporting the vertically stacked independently loaded machine were typically smaller than for the integrated in-line machine.

Benches and Breakers

- Sprayed foam benches offer support that is in intimate contact with the ditch bottom, which can be sized and shaped to address local differences in ditch depth, backfill

density, product density, pipe diameter, and wall thickness, and have a structural response that facilitates controlled settlement onto the padding.

- Traditional practices based on sandbags appear less productive to set than foam benches, and involve the potential to locally ovalize or dent the pipe where the bags are overly stiff or poorly placed. Contractor opinion was that the foam benches were much quicker and less manpower intensive than more traditional sandbag method.
- The transition to from burlap to synthetic bags opens the door to potential short- and long-term problems not experienced with the burlap.
- Precast foam benches appear to be easier to get to the spread and into the ditch, but are more difficult to place and maintain during lowering-in.
- Because precast benches have a fixed thickness, width and length, it will be difficult to achieve their potential design goals while accommodating practical realities such as uneven ditch bottoms, differing fill densities, differing ditch depths, and differing pipe thickness (weight) where class changes, crossings, etc occur
- Foam versus sandbag breakers share the same productivity issues noted for benches. Such breakers must be sprayed to achieve a fit to variable trench width and depth and pipe placement.

Benches after Lowering-In

- For flat straight pipe runs, where the benches were well placed the pipe settled uniformly onto the benches, with moderate compression in foam pads or similar displacement in sandbags in the vicinity of the support.
- Problems were typically experienced where vertical or horizontal changes in direction occurred, as few benches were uniformly loaded, with spans evident. The worst problems occurred for vertical bends (sag- and over-bends). Potential causes for this include:
  - Bench heights not matched to the line of the pipe-string.
  - Bench heights not horizontal over its width in the ditch.
- More likely causes include:
  - Problems in matching the bend orientation to the ditch profile, and,
  - Problems in making tie-in welds.
- Highly uneven loads during lower-in can cause foam benches to split, whereas sandbags appear to survive. Problems appeared worst where tie-ins caused mismatch at sag- and over-bends. However, in no case did the pipe settle onto the ditch damaging the coating during our time on-site.
- The bench crew was found to be much faster than pipe could be lowered in, as this crew was miles ahead of the lowering-in operation.
- On spreads with significant hills and valleys, causing pipe to be strung and joined into many sections, the rather tedious process of tie-in welds appeared to dictate construction progress, with other issues apparently secondary drivers for completion of the spread.

Bedding and Padding – Dynapad

- Dynapad is an inclined vertically stacked processor of spoil that uses multiple shaking screens to separate and grade spoil, and by arrangements within the unit deposits successively coarser fines sequentially into the right-of-way. Dynapad is gravity-fed,

operating over the pipe-string while attached to and suspended there from a "mast" attached to a conventional side-boom. Provisions are included to maintain the screening unit or "mainframe" more or less horizontal, and to rotate this unit.

- The positioning of the screens and the internal operation of the mainframe of Dynapad causes the smallest fines to fall first onto the pipe. Increasingly coarser material is deposited sequentially over a few feet along the pipe-string. The incline angle of the screens coupled with movement of the screens and gravity controls the size of the material passing the screen. These parameters also cause the larger material to shift along the screen until it eventually falls onto the next screen or the pipe-string.
- Where ample fines are accessible to the backhoe feeding Dynapad, the deposit off the last screen can create a layer of cover whose depth ranges from six to twelve inches deep (on average), which is followed by successive layers of increasingly larger fines and rock, the last comprising material that did not pass the bars above the hopper. Because the hopper is fed by backhoe, spoil can be selected whose maximum size suited the requirements for the job.
- Dynapad was used over stretches where rock was present, but not otherwise. Stretches of soil where minimal to no rocks present were padded with backhoes from the spoil pile.
- Forward progress measured over several rocky stretches indicated the Dynapad produced 350 feet per hour on average, with some variation evident in speed depending on spoil conditions. Other data over two short rocky stretches indicated 175 feet in 30 minutes for one stretch and 217 feet in 20 minutes for the second stretch, the best of which indicates 6510 feet in a 10-hour long shift.
- Because of the reach of the backhoe, the Dynapad can feed its hopper from a wide range of spoil, which for this spread permitted the pipe-string to be padded in one pass. The layered backfill from this single pass developed bedding, padding, and cover for the pipe-string of at least two feet, with upwards of three feet deposited in some locations.
- The ability to select fines by loading independently through a backhoe means that with appropriate spoil selection skill startup can proceed with only fines deposited into the ditch. Backhoe operator skill in this context is essential to limit damage to the coating until forward progress develops the layer onto which the coarser fines and other material are subsequently deposited.
- Because the last screen deposits fines onto an already existing layer once steady-state operation develops, and because the spoil was dry, the fill material flows freely onto, around, and underneath the pipe leaving little unfilled the area except below the invert. Continued flow of the fill material appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void.
- Dynapad typically involves use of one padder, one backhoe, and one bulldozer.
- Dynapad can work on either on the shoulder of the ditch, with access to spoil pipes on either side of the ditch or in the right-of-way through movement of the loading backhoe. The small controlled size of the material that drops first onto the pipe coupled with the layered nature of the backfill limits coating damage and develop a compacted layer. This was observed consistently as was layered backfill.
- No operator "technique" was necessary during start up or otherwise for Dynapad, but during startup "skill and experience" are required by the backhoe operator. During this

phase the hoe operator must identify spoil free of unacceptable fill material to limit rock contact until a layer of cover develops over the crown of the pipe. A major advantage of the Dynapad lies in its ability to deposit fill material without the need to move forward along the ditch, as this facilitates startup of the bedding and padding process and limits concern for coarser material impacting the pipe if the initial fill material is appropriately selected.

- Physical inspection showed the initial layer deposited by Dynapad is comprised largely earth. The leading edge of the fill material was loosely compacted, but a foot back where additional material overlaid the fines, physical inspection of the fill deposited over the crown of the pipe-string showed the deposit was compacted.
- Physical inspection where the fill over the crown of the pipe covered by Dynapad was removed as possible during period stops-start cycles. This showed a coating that looked as it did prior to the bedding and padding process, with no evidence of nicks or chips.
- In areas where the spoil was wet, the hopper of Dynapad appeared to be prone to clog, which slowed the process and limited the flow of fill material, with some clumping being evident in the material deposited off the last screen.
- Areas where the ground was hilly revealed that the design of Dynapad limits its motion to one direction unless its mainframe was rotated. Likewise, if it is traversing hills with widely varying angle, the efficiency of the machine appeared to vary. However the machine provides for adjustment to overcome this, where the operator chooses to make such adjustments. Also where working steep hills without adjustments to level or rotate the mainframe there is the possibility of large rocks falling off the bars on top of the hopper and rolling past the padding operation onto bare pipe. This can be remedied by adjustments as needed, or by working machines in opposite directions such that gravity causes the large rocks to roll back off the hopper toward the already padded pipe. Such is the case for all machines, becoming more acute as the incline-angle of the screen is increased.

Bedding and Padding – Ozzie

- Ozzie Padder is an inclined in-line integrated loader and processor of spoil. It couples a single shaking screen fed by a conveyer through a chute to a loader located at the front of the machine. As for Dynapad or any screen-based system, the incline angle of the screen coupled with movement of the screen and gravity controls the size of the material passing the screen. These same parameters cause the larger material to shift along the screen until for the Ozzie it is deposited on the shoulder of the ditch in the wake of the padder. The chute on the Ozzie lies behind an articulated “mouth” at the front of the machine that provides limited manipulation to broaden access and/or aid selection of backfill material. The machine operates on the shoulder of the ditch parallel to the pipe-string, feeding select fill to the pipe-string by a conveyer table that collects fill material from the screen and delivers it to the ditch by extending the table from the machine toward the ditch.
- Because the spoil processor is in-line and integrated to its loader in an Ozzie, access to spoil is controlled by the fines available from a linear track through the spoil windrow. For this reason, the spoil available in the windrow was enhanced by “roaching” the spoil using a bulldozer, adding material where possible and narrowing the windrow to better match the mouth of the padder.

- Where the fines available from the spoil are limited, a second pass and sometimes third pass is needed to provide the specified bedding depth and padding cover. As the machine efficiently separates useful material, little useful material remains after a pass through the windrow, leading to diminished returns from a second or third pass unless new material is roached into to the windrow or the windrow is reshaped with spoil that was not used on a prior pass.
- For in-line integrated machines like the Ozzie, efficiency is controlled by the length conveyer table, to facilitate access to spoil further from the ditch, and the amount of fines that are available from the windrow of spoil.
- Bedding and padding efficiency is influenced by the quality of the ditching, as heavier Ozzie machines must remain well off the edge of the ditch. The weight of heavier Ozzie machines can limit is use where the main spoil pile is placed over adjacent hot lines in the right-of-way. This too limits efficiency, as it limits the supply of available spoil. Ditch quality also affects the volume of fill material needed to complete the bedding, padding, and cover.
- Bedding and padding reaching the pipe from an Ozzie appears to be homogenous in size and constituents throughout the cover.
- The Ozzie was used over stretches where rock was present. Stretches of soil where minimal to no rocks were present were padded with backhoes from the spoil pile.
- Forward progress was variable, depending on the size of the ditch as well as the quality and availability of the spoil. Measured progress in straight runs through several rocky stretches indicated the Ozzie produced 300 feet per hour on average. Where multiple passes were needed, productivity dropped in proportion to the number of passes made. Where the spoil was rich in fines, a single pass provided bedding, padding, and cover for the pipe-string to depths that reached one to two feet. The best productivity was estimated on average at a mile per 10-hour shift.
- Progress varied relative to trench width and depth. For example, 1 hour and 15 minutes was taken to cover a 0.2 mile long stretch through a wide turn. In contrast, the same amount of time was needed to cover a 0.6 mile long straight stretch using one padder along ditch that was consistently four feet wide.
- Ozzie machines working in tandem over rich spoil were highly productive, offsetting the need to reposition a single padder for multiple passes
- In observing extent of fill once both sides of the pipe were padded, coverage looked complete, as the fill extracted from the spoil was fine enough to flow in and leave no observable voids.
- The depth of padding above the pipe averaged in the range of 12 to 18 inches.
- Once the bedding and padding process had achieved steady state production, fill material off the screen flowed freely underneath the pipe, with little unfilled the area except below the invert. Continued flow of backfill appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void. The fines in the fill appeared to drop onto the already deposited material and remain in place, whereas the larger material rolled off these fines ahead of what remained close to the pipe, and into the ditch bottom. Consequently, while not inherently designed to produce layering of the deposited fill, in steady-state operation the coarser material

"rolled" ahead of the fines to fill areas remote to the pipe, while fines remained near the pipe. Industry experts associated with companies that sell or operate such equipment note this inherent property of the fill material as a key to the success of such equipment.

- The behavior during startup differs from steady state, as the generally uniform fill falls from or was projected off the conveyer table randomly onto the pipe absent operator controls designed to affect improved behavior. During uncontrolled startup and over the first few feet of travel larger rocks that passed the screen can fall directly onto the pipe-string. During the startup phase, the fill material serving as bedding flowed freely underneath the pipe, with little unfilled the area except that below the invert. Continued flow of the fill material appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void. Startup had rock whose size approached the clear pitch of the screen contacted the pipe-string, with occasional impacts occurring squarely at the crown.
- It follows that little damage is anticipated for the Ozzie during steady-state operation because the already present fill material limit direct contact and the larger material rolls harmlessly down to the ditch bottom. However, damage might be anticipated during startup and the first few feet of the bedding and padding operation unless the spoil is roached selectively to limit this problem.
- Operators and personnel working with the Ozzie padder note techniques are available to limit this damage. First, as the richest zone of fines lies toward the bottom and center of the spoil, an effort is made to articulate the mouth of the padder into this area during startup. Another technique relied on directing the flow from the conveyer table against the far wall of the ditch, filling that side with overflow onto the top of the pipe-string, which was followed by flow onto the now covered crown to fill the side adjacent the padder, such that the flow into the trench does not impact the pipe.
- Thus, operator "technique" gained through experience or training can be important to the successful and damage-free use of the Ozzie padder.
- Physical inspection showed the steady-state layer deposited by the Ozzie was typically a mix of small stones and earth. The leading edge of the fill material was loosely compacted, as was the material a foot or more back, in spite of additional material being overlaid by other spoil.
- Physical inspection where the fill over the crown of the pipe was removed at the end of a padding run showed a coating that looked as it did prior to the bedding and padding process, with no obvious evidence of nicks or chips.
- Where because of the topography the spoil was wet the Ozzie screen and loader appeared to be prone to clog or pack with fill material, which slowed the process and limited the flow of fill material. Some clumping also was evident in the material deposited as it rolled down the leading face of the bedding and padding.
- Where the ground was hilly the design of the Ozzie limits its motion to one direction. If it is going down a steep hill, there is the possibility of large rocks falling off the screen on top of the hopper and rolling past the padding operation onto bare pipe. This can be remedied through use machines working in opposite directions such that gravity causing large rocks to roll back off the hopper would continue their movement toward already padded pipe.

Bedding and Padding – General

- Forward flow of the fill material and the natural selectivity for coarser material to roll down the slope created by the angle of repose has been understood for decades as fundamental to success in bedding and padding, and a design parameter for such equipment. This forward flow once the pipe-string is enveloped is controlled by soil mechanics through the angle of repose for the soil, which depends on the nature of the soil, including the size and to a lesser extent the shape of the fill material. Any bedding and padding machine that provides for these aspects should supply well compacted fill that flows around the pipeline, with the little chance for coating damage.
- While contact with the pipe is necessary for damage, whether or not damage is done depends on the resistance of the coating to impact and other forms of contact as well as the energy and the nature of the contact. Nevertheless, a machine that limits contact is a hedge to avoid coating damage. So long as adequate cover is developed over an initial section of the pipe, and subsequent fines flow forward and envelop the pipe, the fill added should cause no chipping or other coating damage. Success in this context is largely dependent on fill that flows freely, which occurs most easily for dry fine fill material.

Rock Impact and Coating Quality in Relation to Safety and Reliability

- Some heavier modern coatings, such as brown-coat FBE, appear highly resistant to impacts with sharp rather large aggregate falling from distances the order of six to eight feet. For example, jeeping over 400 feet where aggregate passing a 2-inch square screen projected off a conveyer table and falling such distances onto the crown of a larger-diameter pipe-string revealed only one coating chip. Other ad hoc experiments on a discarded ring of pipe showed the coating to be quite resistant to damage, at least at moderate temperatures.
- The available results indicate that coating damage resistance is a major factor in the viability of bedding and padding procedures, as tough durable coatings can resist damage. This limits the relative significance of bedding and padding practices designed to avoid damage where such coatings are used. Developing performance-based specifications for coatings and construction practices seems viable in this context, with validation needed to make them as effective as possible in balance with longer-term concerns related to coating quality.
- More formal evaluation of coating damage resistance under parametric contact conditions is necessary to develop a quantitative understanding of what contact bedding and padding or related construction practices are viable versus problematic as a function of coating type and thickness, and factors affecting their properties such as temperature, thereby maximizing productivity without jeopardizing safety.
- Consideration should be given to typical as well as extreme conditions, as construction sites seldom involve only routine scenarios.
- The role and effectiveness of CP should be a consideration in developing and validating any one-size-fits-all construction specification that involves coating quality.
- A forum organized around coating damage resistance and longer-term durability would identify needs/benefits, if any, along with related drivers would and so define a path forward, providing value to all stakeholders.

Rock Shield

- This generic class of products saw limited use on the spreads visited, possibly because various concerns exist for the use of polymer-based coatings.
- The use of "reverse rock shield" in the form of foam sprayed on the rock local to each bench appeared to provide effective protection during lowering in, avoiding concern for CP shielding where such foams are applied directly to the pipe-string.

Trench Stability

- Data are limited to nonexistent in reference to practical field conditions where trench stability due to flow along the ditch or vertical migration in the ditch would be an issue.
- There is evidence that companies operating through hilly or mountainous terrain with significant rainfall potential experience trench stability problems due to flow along the ditch or vertical migration in the ditch – but there is no clear evidence to indicate the significance of this concern or to identify factors that control when it becomes practically important.
- Where vertical trench stability appears to be a problem based on experience, select backfill might be a consideration, with rocks larger than a few inches are excluded. But, as the data are limited to support such actions, this decision must reflect cost-benefit considerations.
- A forum organized around trench stability might be effective in defining the issues, if any. Potential considerations include geology, topography, and breaker spacing, and company-specific experience. Needs/benefits, if any, along with related drivers would identify a path forward, and so provide value to all stakeholders.

Future Developments

- "The industry is going toward bottom padding in the ditch before laying down the pipeline so that it will better conform to the shape of the ditch" according to Mr. Turnage, for which combination crusher/padding machines appear viable, although they currently are very slow.
- The hope that either a rock trencher/crusher and/or new coatings that were more resistant to chipping could be developed, making issue of rocks moot, was expressed by Mr. Klaymar.
- A forum organized around necessary/beneficial developments and related drivers and constraints might be effective in defining the issues, if any, and identifying a path forward with potential value to all stakeholders.

The KNI System – Layered Backfill

- Layered backfill does develop through use of Dynapad, which grades and places three tiers of fill material – fines, smaller sized stone and fines, and a third layer of larger sized stone. This was verified at all sites visited where Dynapad was used, with no evidence of damage evident in any case.
- Whether this finer-quality layered fill material affects the integrity and reliability of the pipeline as compared to other padders depends at least on operator skill and experience in regard to the other padder, the nature of the coating used in regard to its resistance to damage, and the eventual presence of adequate and reliable CP.

- Corrosion that might ensue at such coating defects becomes a threat to integrity only where the CP is unreliable or inadequate, neither of which is a practical concern early in the life of a new pipeline. However, such chips can become a concern later in the life if, when, and where the CP system becomes unreliable or inadequate – both of which are regulatory issues.

The KNI System – Pipeline Support Method

- Limited observations on Market Link suggests these are precast foam benches, but literature documenting this and their design as a function of backfill density, product density, ditch depth, and pipe diameter and wall thickness to selectively control their failure was not available.
- Viscoelastic theory and related considerations indicate the structural and failure response of foam structures complicated with stress imposed locally as well as nominally being important factors that affect their behavior. Consequently, selectively controlling bench "failure" under locally different backfill density and ditch depth typical of most trenches, and uneven loadings during lowering-in and due to limited practical control over local alignment of the will be complicated and difficult at best.
- However, use of compliant materials with a suitable foam density and viscoelastic time constant as has been done beginning in Canada since the 1980s using a sprayed in-situ foam bench appears viable for the spreads observed. Pipelines so installed should settle onto their bedding, as continued time-dependent compression develops.

The KNI System – Ditch Stability and Geotextile Fabric

- KNI suggests ditch stability is compromised in the horizontal direction due to water flow along the trench bottom, which is most prevalent where the gradient due to hills is present, and also notes vertical instability occurs due to change-in-state under water saturation. Both forms of instability appear feasible and experienced to some degree, as might be vertical instability due to freeze-that cycles. However, the extent of vertical instability and related padding washout is however unknown, and its practical industry-wide significance is yet unproven, although it is credible based on limited field data.
- As yet use of geotextile as laid above layered backfill by Dynapad is unproven in stabilizing vertical washout[6].
- However, one company has limited sand washout under some circumstances by placing a non-woven geotextile fabric (Nylex 4553) on the padding, and extending it up the sidewall of the ditch. This placement is in strong contrast to the location associated with Dynapad.
- A forum organized around this topic might be effective in defining the issues, if any. Issues such as geology, topography, and breaker spacing are potential topics, along with company-specific experience.

Modifications that Merit Consideration

- Unless independently evaluated but not broadly known or reported, consider abandoning the rot-resistant higher strength polymeric replacement for conventional burlap for sandbags.
- As modern coatings in heavy application appear resistant to impacts with sharp rather large aggregate, consider widespread use of such coatings where rock is anticipated. A

ranking of coating resistance would enhance such decisions. As this requires data that define coating performance, consider supporting this through related experiments to quantify coating damage resistance under practical field conditions in lieu of standardized industry tests that bear little resemblance to the field.

- As coating damage resistance can be a major factor in the viability of bedding and padding procedures, consider developing and validating performance-based specifications for both the coatings and construction practices.

Summary and Major Conclusions

Increased demand for transported fuels and other hydrocarbons has depleted supply basis near early markets, leading to increasingly remote supply basins that occasionally are located in challenging geographic and climatic conditions. Shifting population centers and related markets such as distributed power generation have likewise force pipeline construction onto challenging routes across mountains and through other geographically difficult areas. This has led to the evolution of new or emerging construction practices, as well as developments in thinner and stronger line pipe, and new coatings. Such improvements coupled with developments in bedding and padding practices for hard, rocky ground could add value through increased safety and reliability due to reduced extent and/or severity of construction related coating damage that necessitates repairs.

This project assessed enhancements in safety and productivity possible through recently developed construction practices, and identified and evaluated opportunities for cost reduction, improved pipe protection, and decreased construction created pipe/pipe coating damage that could be realized with new or emerging pipe support and padding/backfill practices. The extent to which safety and productivity were enhanced through recently developed pipe support and padding/backfill practices were evaluated relative to existing practices, for the range of ditching conditions where the benefits of such enhancements could be evident.

Safety and reliability have been evaluated in balance with construction productivity using field data and observations and metrics that reflect safety and characterize productivity and possible cost reduction. Empirical comparison of current and emerging or new practices and equipment in terms of productivity as well as safety and reliability provides to establish what works best and under what conditions. For purposes of this project, the timeline for new or emerging is measured in reference to the introduction of technology that produces layered-backfill, as this comprises the last major step in flat screening technology to separate select backfill, in contrast to the prior major step that involved the shift from a rotary to flat screening. Safety and reliability were defined in reference to threats to pipeline integrity, and the relative significance of these threats. This led to parameters that minimize external corrosion and mechanical damage as measures of enhanced safety and reliability, which from a construction perspective translate to changes in pipe shape damage as practical field measures.

Data were gathered subject to the practical constraints imposed by use of construction equipment and the contractor's permission to enter or approach the ditch for "hands-on" measurements and close-up observation. Accordingly, safety and other conditions dictated by the contractor were complied with.

On-site measurements and observations made in reference to the five sites considered lead to the following general conclusions.

- The performance of bedding and padding machines is dictated by the properties of the soil and soil mechanics, in addition to design and operating features that might be unique to a given machine.
- Differences in performance characteristics between integral in-line loader and screen machines and independently loaded stacked vertical screen machines preclude a one-size-fits-all basis for machine selection. Economics and many other factors dictate overall productivity on the spread and constrain decisions – for example, where many tie-ins are involved because of routing or topography, the tie-in welds appear to control, and this is but one such factor.
- Coating damage resistance is a major factor in the viability of bedding and padding procedures, as tough durable coatings were resistant to damage.
- The relative significance of bedding and padding practices designed to avoid damage is limited where adequately damage-resistant coatings were used. Performance-based specifications for coatings and construction practices seem viable in this context, with validation needed to make them as effective as possible in balance with longer-term concerns related to coating quality.
- The behavior of the fill material is also a critical bedding and padding parameter, as forward flow of the fill material and the natural selectivity for coarser material to roll down the slope created by the angle of repose lead to flow of fill under and around the pipe-string. Forward flow once the pipe-string is enveloped is controlled by soil mechanics through the angle of repose for the soil, which depends on the nature of the soil, including the size and to a lesser extent the shape of the fill material. Any bedding and padding machine that provides for these aspects should reasonably supply compacted fill that flows around the pipeline, with the little chance for coating damage. Industry personnel associated with companies that sell or operate such equipment note this inherent property of the fill material is a key to the bedding and padding success.
- Some technology starved areas exist in regard to the aspects of pipeline construction considered, for which several recommendations follow in the next section.

A number of less general but still important conclusions follow from the measurements and observations made at the five sites considered. These include:

- Where it is "possible" to machine ditch the rock in lieu of blasting in reference to all factors from productivity through economy and safety, subsequent construction is facilitated and productivity enhanced.
- Sprayed in-situ foam offers support that is intimate with the ditch bottom, can be sized and shaped to address local differences in ditch depth, backfill density, transported product density, pipe diameter, and wall thickness, as well as structural response that facilitates controlled settlement onto the padding. When sprayed onto the trench wall above the support, sprayed foam offers reversed rock shield, protecting against very likely damage in tight ditches during lowering-in.
- The transition from burlap to synthetic bags opens the door to potential short- and long-term problems beyond those experienced with burlap.

- Problems in matching horizontal and vertical ditch profile to pipe profile at tie-ins tends to cause uneven loading on benches that can cause their failure, however in no case was there evidence of pipe to ditch contact that involved damage to the coating.
- Dynapad developed layered backfill, grading and placing three tiers of fill material. But, whether this enhances integrity and reliability depends at least on the damage resistance of the coating.
- Where appropriate skill is practiced, an Ozzie (and presumably other similar designs) can bed and pad without undue damage to pipeline coatings, at lease for the coatings and trench conditions addressed in this project. Significant to this conclusion is the skill of the operator during startup through steady-state operation, the coating used, and the screen size involved.
- Data regarding horizontal and vertical trench stability in the presence of water and related washout are limited to nonexistent, nor is there much practical field data to identify conditions where trench instability due to flow along the ditch or vertical migration in the ditch would be an issue.
- Some areas have been identified for future development. These focus combination crusher/padding machines and the continued evolution of coatings resistant to damage, making issue of rocks moot.
- Analytical considerations indicate the complicated structural and failure response of foam structures make it very difficult to achieve selectively control bench "failure" – as suggested for the KNI patent-pending precast foam bench – given the locally different conditions and loadings typical of most trenches.
- Use of geotextile laid above layered backfill by Dynapad is unproven to stabilize vertical washout. Control of sand washout under some circumstances by placing a non-woven geotextile fabric (Nylex 4553) on the padding, and extending it up the sidewall of the ditch involves placement is in strong contrast to the location associated with Dynapad.
- Forums organized around topic such as ditch stability, new technology, might be effective in defining the issues, if any.

Recommendations

- Data concerning coating damage resistance are limited in reference to contact conditions and what size/depth chip or scrape is a short- or long-term threat. A formal evaluation of coating damage resistance under parametric contact conditions should be considered to quantify this in reference to contact bedding and padding or related construction practices are viable versus problematic as a function of coating type and thickness, and factors affecting their properties such as temperature, thereby maximizing productivity without posing a practically significant short- or long-term threat or burden on maintenance.
- Because tough durable coatings were observed to resist damage, damage resistance becomes a major factor in the viability of bedding and padding procedures. As the viability of coatings becomes better characterized, consideration should be given to performance-based specifications for coatings and construction practices, with validation drawn from the results of the above noted parametric coating evaluation. The role and effectiveness of CP should be a consideration in developing and validating any one-size-

fits-all construction specification involving performance-based coating and bedding and padding practices.

- Some data indicate that horizontal and vertical trench stability and related washout pose a threat yet little is known to identify conditions where trench instability due to flow along the ditch or vertical migration in the ditch would be an issue. Consideration should be given to a forum organized around this topic to define the issues, if any, and identify a relevant path forward.

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(a work in progress)

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Appendices
"RSPA-INGAA
Bedding and Padding
and Related Construction Practices "
draft final report
December 2004

Appendices

This section contains details in support of the body of this report in the form of three appendices as follows:

Appendix A – Field Measurement Protocol
Appendix B – Reporting Format
Appendix C – Field Reports (as filed without editing or concurrence)
Appendix D – Soils Reports
Appendix E – Viscoelastic Aspects of Bench Design

Appendix A presents the field measurement target protocol, while Appendix B presents the target report format. Appendix C presents the site visit reports, while appendix D presents the soils reports as determined for selected sites. Finally, Appendix E presents results done to better understand the structural performance of benches made of polymeric foam.

References cited in the body of the report are numerous, and few additional references appear in these appendices. For this reason it is convenient to retain the numbering system used in the body of the report. When new references are cited, they appear in the appendices as footnotes. Footnotes used herein are numbered independently from the body of the report. In contrast, where figures appear here in that are not addressed in the body of the report, it is impractical to retain the numbering system from the body of the report. Where figures or tables presented in the body of the report are cited, use is made of the same number used in the main text. Where new figures or tables are introduced, they are numbered with a scheme that couples a letter prefix corresponding to each appendix coupled with the figure or table number as appropriate.

Appendix A – Field Measurement Protocol

What follows is the field guidelines as developed prior to the visit to Kern River. This protocol evolved in light of the experience gained at the Transco spread, and continuously thereafter as what could or could not be expected on-site became increasingly defined.

Roles and Responsibilities

Develop visual observations over the course of the day, and comment on those observations according to the Schedule of Activities. Obtain items to support the Schedule of Activities attached, and make arrangements for local laboratory support as outlined in the same schedule. Direct the lab to hold the samples for up to 6 months.

Target Schedule of Activities

Prior to site visits:

- Obtain and read the padding/backfill and pipe support project specifications during transit to the primary site, and note critical dimensions that characterize bedding and padding, and backfill procedures.

At each site:

- Determine the pipe diameter and wall thickness
- Identify and record the manufacturer names, and their equipment designations for all equipment used, for each of the operations observed.
- Photograph typical aspects of each operation
- With reference to the specifications concerning inspection, determine the presence of inspectors and the scope of activities observed by inspector in all activities

Observe and Characterize Pipe Support

Sand bags if used for support –

- count the number of sand bags per bench and photograph what appears typical
- measure the center-to-center distance between benches
- through discussions with the foreman, determine crew size, equipment used, and number of benches set per day, as basis to estimate cost per bench

Observe lowering-in

- estimate the cross-section area of several benches to estimate support pressure
- determine if every bench appears to be supporting the pipe uniformly? If not, are there spans, and how big: How often? Photograph what appears typical.

Screened subsoil mounds for support rather than sand bags –

- measure the time to create several supports and photograph what appears typical
- measure the center-to-center distance between supports
- through discussions with the foreman, determine crew size, equipment used, and number of supports set per day, as basis to estimate cost per support

Observe lowering-in

- estimate the cross-section area of several supports to estimate support pressure
- determine if the pipe settles onto the supports equally or unequally between a typical set of supports If not, are there spans, and how big: How often?

Bedding and Padding Operations

- determine the number of screens and measure screen mesh size openings
- measure the height of pipe over trench floor in several sites to determine the extremes and what is typical along a joint of pipe, and for five or so randomly chosen joints
- determine the size of the ditch relative to the pipe and contrast to specs
- observe rate of forward progress as a function of typical operation over the course of the day, and report extremes as well as average progress
- determine the number of passes to affect coverage to suit the specs, and measure typical cover over the pipe, and photograph what is typical
- observe the extent of fill under the pipe, as opportunities are present, as for example when the crew completes a pass, or breaks for lunch, and photograph what is typical
- photograph the native backfill and estimate the size and roughly estimate the range of rock sizes present
- identify the pieces of equipment involved, their sizes, and the man power employed for padding as the basis to estimate costs
- measure size of padding material and obtain a sample for lab sieve test
- locate local lab and determine sample characteristics in terms of particle size distribution – obtain 4 to 6 such samples per site, using judgment to represent the range of geological conditions experienced (purchase a pail and a supply of heavy-duty bags for this purpose – satisfy the local lab's requirements on sampling practices.
- observe and determine if padding material introduced into the trench impacts the pipe after one or two passes are made and pipe is not covered, walk the crown of the pipe and use holiday detector (jeep) to check for bare metal exposures. Do this for each different type of padding machine in use on the spread. Note: Exposures are most likely to occur from clock positions 9 to 11 and 1 to 3, or in the vicinity of 30° to 45° from the square padding impact point – see Figure A1 for clues as to location
- when the crew has stopped a padding run, from the vicinity of the toe of the padding (where the pipe is just uncovered), back onto the increasingly deeper cover, drop a small ball that weighs a few ounces (e.g., use white

golf balls) onto the pipe from a fixed height, such as your waist, targeting a spacing of ~ 3 inches for a distance of about 24 inches. Leave the golf balls in place – locate rulers to serve as vertical and horizontal scales, and photograph each site to capture the relative penetration and degree of compaction typical of each different type of padding machine in use on the spread.

Backfill Operations

- observe backfill process to document backfill rocks falling through the padding and contacting, or coming into close contact with, the pipe
- with reference to the specifications concerning inspection, determine if the inspectors observe the backfill process along the spread
- estimate the nature of the backfill relative to the presence of rocks, their sizes, and proximity to the pipe wall

Check out variances

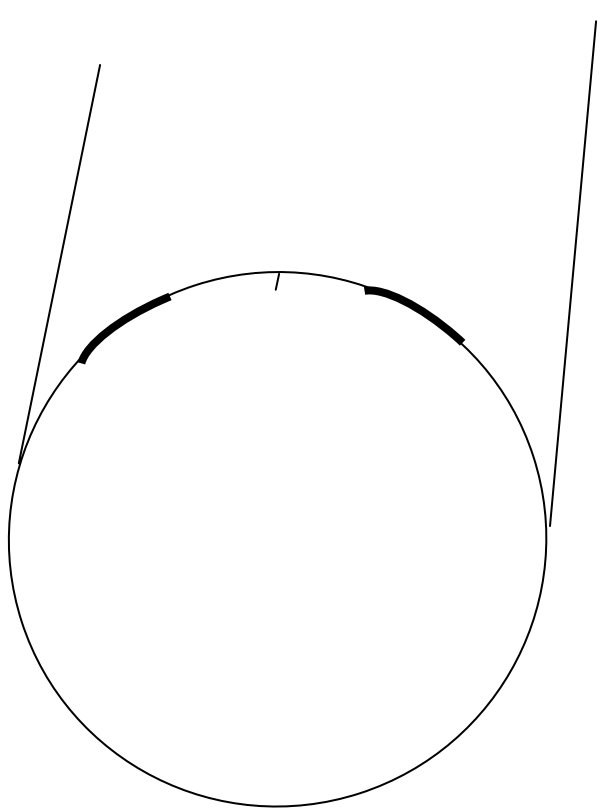
Through discussion with spread management determine

- what happens in extreme rock conditions
- in what type of conditions are padding machines not used

On the Ride Home

- while still fresh in your mind, use this time as necessary to make notes or documentation in addition to that made daily on the spread

Figure A1 follows



Appendix B – Reporting Format

Line Pipe Description – diameter, thickness, coating and unique descriptors

Pipeline and Right-of-way Description – owner, general location or routing, transported product

Spread Description – topography and geography, and general practices in use, the nature of ditching, type and quality of spoil, etc.

Equipment and Personnel – list all relevant equipment and support personnel, management, inspection etc.

Supports – Report the support scheme and details relating to materials, type of construction, and aspects indicative of cost and quality. Address distances, sizes, features, and consistency versus variability, etc. Address measures related to productivity and quality as they effect construction and might impact long term pipeline functionality. Report influence on pipe shape and or aspects related to damage to pipeline (denting/ovalization) and coating. Characterize and quantify, or provide qualitative data.

Breakers – Report the support scheme and details relating to materials, type of construction, and aspects indicative of cost and quality. Address distances, sizes, features, and consistency versus variability, etc. Address measures related to productivity and quality as they effect construction and might impact long term pipeline functionality.

Bedding and Padding Operations – Report and discuss equipment and its function/operation, when and why it is effective, strengths/weakness, measures of productivity, quality in reference to bedding and padding, such as flow around and compaction, fines, necessary technique/skill, possible enhancement through modifications, etc. Characterize and quantify, or provide qualitative data. Assess the role of the trenching, in reference to productivity in trenching and any relationships to same or subsequent functionality or integrity of the pipeline. Address distances, sizes, features, and consistency versus variability, etc, all as a function of the trench and spoil conditions, and the amount of equipment and personnel involved. As relevant address layered backfill, and always report coating condition and possible damage, whenever possible using jeeping practices. Take pictures often, and of everything. Physically inspect everything noted, and document. Measure depths, compaction, etc, and qualify as a function of conditions. Do so for all aspects from trenching, through final backfill operations.

Prepare notes for field reports nightly.

Appendix C – Field Reports
(as filed without editing or concurrence)

Task Three gathered qualitative and quantitative data characterizing the metrics identified in the body of the report, through field observations and discussions with industry experts, observing the strengths and weaknesses of current, emerging, and new equipment or practices. This appendix presents details of the field studies in the format of the reporting set forth in Appendix B, gathered according to the target protocol presented in Appendix A. Photographs support these reports are included within the text, appearing nearby the text that is illustrated in reference to the photo. These field reports are presented as filed, without editing, or the quality checks and concurrence of all involved. Such text appears in the body of the report, along with interpretation or analysis of the observations as appropriate. Additional photographs can be found in Figures 2, 3, 4, and 5 for Sites One to Four, respectively.

Site One – Market Link (Transco/Williams)

The Market Link Project involved construction of a 42-inch diameter pipeline coated with fusion-bonded epoxy through eastern Pennsylvania and western New Jersey. The wall thickness varied as required for road crossings and class changes, consistent with class location and code requirements. Further description of the site can be found in the body of the report, and in Figure 2. The field report follows verbatim, as filed.

Line Pipe - 42" Brown-coat FBE on nominal wall thickness of 0.429"

The ditch on all spreads was created with backhoes and because of the large rocks present had variable width and occasionally uneven depth. Because of this, and the larger diameter of the pipeline, there was a significant amount of material required to meet the bedding and padding specifications. The spreads active were being built by different contractors, one using an Ozzie padder and another using a Dynapad. Because these spreads were active through areas involving rock as the contract was initiated, the time on-site was limited. Consequently, the observations focused on bedding and padding, which also was the focus of the measurements and reporting. The majority of the observations reflect operations with largely dry spoil. In contrast to areas where the spoil was dry, wet spoil appeared to cause problems with most aspects of the bedding was padding process.

Dynapad spread

Equipment and Personnel

- One Dynapad padder
- One backhoe serving the padder
- One bulldozer ????
- Four people involved in bedding and padding operations, and related restoration.
    - One padding/backfill inspector
    - One operator on Dynapad
    - One operator for the backhoe
    - One operator for bulldozer
    - One site manager walking with equipment
- An inspector was available during bedding and padding, and backfill operations

Supports (Sandbags)

- The typical number of sandbags varied from support to support, ranging from three to six in the soft soil areas. Higher numbers of sandbags was used in instances where rises, sags and turns occurred to accommodate inconsistencies in ditch depth and places where bends in the pipe-string apparently did not neatly match the ditch profile.
- The center-to-center distances varied widely from terrain to terrain. In rocky and hilly sections the bags were spaced more consistently.

Supports (Foam Benches)

- Foam benches were set over the ditch bottom on a short stretch of the right-of-way in advance of lowering-in through that section. These benches were precast and apparently made of polyurethane foam whose formulation was not available. All benches had a fixed thickness, width and length, being the order of several feet long and roughly one foot square. As they were light-weight and easily handled, their placement would be simple and require only a light truck and two laborers (driver and setter). By virtue of their rather disorganized placement, a laborer would be needed to reset them during lowering-in. Their constant thickness and width would result in inconsistent support to the pipe because of the variable depth of the trench due to the presence of large rock encountered during ditching.
- One truck would be positioned ahead of the lowering-in crew. They were responsible for the placement of the sandbags in the trenches for the benches. The initial two days of observation yielded terrain that was sandy and rocky in stretches. When the soil was consisting mostly of fines, a few sandbags were placed great distances from each other and in other places the pipe simply laid on the trench floor. In the rocky stretches, the sandbag count and frequency increased to match the terrain. No attempt by the padding crew was made to adjust any pipe supports that might have not seemed sufficient.

Breakers

- There was no opportunity to observe breakers during the short time on the spread.

Bedding and Padding Operations

- The Dynapad is an inclined vertically stacked processor of spoil that uses multiple screens to separate and grade spoil, and by arrangements within the unit deposits successively coarser fines sequentially into the right-of-way. Dynapad is gravity-fed, operating over the pipe-string while attached to and suspended there from a "mast" attached to a conventional side-boom. Provisions are included to maintain the screening unit or "mainframe" more or less horizontal, and to rotate this unit. The shaking or vibrating screens are steeply inclined (~45° in optimal use, to limit dynamic screen blinding), being fed by a conveyer from a holder that collects fill material from hopper. Primary separation occurs above the hopper through use of steel bars with a clear spacing that passes material about 5-inches on one dimension. These bars run across the full length of the hopper. These bars serve to reject rocks and clumps of fill material larger than this size, and can be raised to a vertical position to dump debris laying these bars into the already padded ditch. This helps limit static blinding of this primary screen. As with the screens below, the barred entry to the hopper lies at a steep angle to horizontal, which helps gravity move oversize spoil off the back of the screen or hopper. Spoil passed through the bars is transferred from the holder onto a conveyor belt to increasingly finer screens. The clear pitch of the first screen is designed to pass material the order of two inches on a side, measuring about 2.25 by 2.25 inches, while the clear pitch for the second screen measured about 1.5 by 2.25 inches, the

latter dimension being parallel to the trench. The positioning of the screens and the internal operation of the mainframe causes the smallest to fall first onto the. Increasingly coarser material is deposited sequentially along the pipe-string. Thus, soil and rock larger than the last screen but smaller than the first falls onto the fines passed by the last screen, while material not passed by the bars falls onto the previously deposited padding as it falls off the back of the hopper. The incline angle of the screens coupled with movement of the screens and gravity controls the size of the material passing the screen, such that the material passed tends to be smaller than the clear pitch of the screens. These parameters also cause the larger material to shift along the screen until it eventually falls to the next screen or onto the pipe-string. Where ample fines are accessible to the backhoe feeding the padder, the deposit off the last screen can create a layer of cover whose depth ranges from six to twelve inches deep (on average), which is followed by successive layers of increasingly larger fines and rock, the last comprising material that did not pass the bars above the hopper. Because the hopper is fed by backhoe, spoil can be selected whose maximum size suited the requirements for the job.

- The size of the trench relative to the pipe was measured in several areas where the pipe had been lowered-in. In some places the width of the ditch was two to three times the diameter of the pipeline. This was much wider than the minimum width based on company specifications, which based on discussions with help on-site typically required twelve inches more than the outside diameter of the pipe.
- Based on limited site observations, the Dynapad was used over stretches where rock was present. Stretches of soil where minimal to no rocks present were padded with backhoes from the spoil pile. Forward progress was measured over several rocky stretches, which on average indicated the Dynapad produced 350 feet per hour on average, with some variation evident is speed depending on spoil conditions.
- Because of the reach of the backhoe, the Dynapad can feed its hopper from a wide range of spoil, which for this spread permitted the pipe-string to be padded in one pass. The layered backfill from this single pass developed bedding, padding, and cover for the pipe-string of at least two feet, with upwards of three feet deposited in some locations.
- Because the first screen is positioned to deposit fines onto the pipe-string immediately on startup, and because the spoil was dry, the fill material serving as bedding flowed freely underneath the pipe, with little unfilled the area except below the invert. Continued flow of the fill material appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void.

- The padding operation involved one Dynapad padder, one backhoe, and one bulldozer. No tie-ins were done while on-site, so there was no way to observe how such areas were dealt with.

Layered Backfill, Coating Condition and Possible Damage

- Because of the limited preparation time, there was no opportunity to obtain jeeping equipment. However, during start-stop cycles, the contractor allowed entry to the ditch, which facilitated periodic evaluation of coating quality as well as the nature of the layered backfill. For this job the light-weight Dynapad could work on either on the shoulder of the ditch, with access to the main spoil pipes deposited over the two hot pipelines operating in this right-of-way. The initial screen's mesh size and gravity feed of the material that drop to and impact the pipe off the first screen are anticipated to minimize coating damage and develop a compactable layer because of the rather small size of the fines deposited off the first screen. This was observed, along with the anticipated layered backfill created by successive deposits due to the multi-screen design of this machine.
- The fill material off the first screen dropped around the pipe, with the hopper fed until the pipe-string was covered, and the fines were observed to flow forward enveloping the pipe-string over a distance of several feet. No operator "technique" was necessary, as the amount of fines available at startup did not require forward motion to supply feed for the hopper, nor was technique needed to ensure that material adjacent to the pipe-string was comprised of fines. Flow of the fill material forward along the pipe-string once the pipe-string is enveloped is controlled by soil mechanics through the angle of repose for the soil[36], which depends on the nature of the soil, including the size and to a lesser extent the shape of the fill material. A bedding and padding machine that provides for these aspects should supply well compacted fill that flows around the pipeline, with the least chance for coating damage. Significantly, forward flow of the backfill and the natural selectivity for fines to precede coarser material down the slope created by the angle of repose has been understood for decades as fundamental to success in bedding and padding[37,38], and a design parameter for such equipment. While an important parameter, whether or not damage is done depends on the resistance of the coating to impact and other forms of contact as well as the energy and the nature of the contact. Nevertheless, a machine that limits contact is a hedge to avoid coating damage. So long as adequate cover is developed over an initial section of the pipe, and subsequent fines flow forward and envelop the pipe, the fill added should cause no chipping or other coating damage. Success in this context is largely dependent on fill that flows freely, which occurs most easily for dry fine fill material.
- Physical inspection showed the initial layer deposited comprised largely earth for this jobsite. The leading edge of the fines was loosely compacted, but a foot back where additional material overlaid the fines, physical inspection of the fill deposited over the crown of the pipe-string showed the deposit was compacted.
- Physical inspection where the fill over the crown of the pipe was removed as possible during period stops-start cycles showed a coating that looked as it did prior to the bedding and padding process, with no evidence of nicks or chips.
- Padding material was not obtained for sampling at this site due to the limited time available to facilitate such studies.
- The depth of the padding developed because the hopper can be filled without forward progress coupled with the double layering of increasingly coarser fill

material keep large rocks coming off the back of the hopper from reaching the crown of the pipe-string, and appeared to likewise limit this during subsequent backhoe-backfill operations.

- While not specifically observed, the Dynapad operator indicated that on a good day, and with a skilled backhoe operator, upwards of 9000 feet could be covered over flat stretches during a typical day-long shift. This claim cannot be substantiated and seems extreme, and is included here only for the sake of completeness.
- In one short stretch through a sag area, where because of the topography the spoil was wet, the hopper appear to be prone to clog, which slowed the process and limited the flow of fill material, with some clumping being evident in the material deposited off the first screen.
- Areas where the ground was hilly revealed that the design of Dynapad limits its motion to one direction. If it is going down a steep hill, there is the possibility of large rocks falling off the screen on top of the hopper and rolling past the padding operation onto bare pipe. This can be remedied through use machines working in opposite directions such that gravity causing large rocks to roll back off the hopper would continue their movement toward already padded pipe. Such is the case for all machines, becoming more acute as the incline-angle of the screen is increased.

Backfill Operations

- The backfill process was accomplished with a backhoe drawing fill material from the spoil piles. The padding had sufficient depth to preclude large rocks from reaching the crown of the pipe-string.
- A bulldozer was used to top-off the trench after the backhoe was finished.

Ozzie Spread

Equipment and Personnel

- One Ozzie padder
- One bulldozer creating windrows of spoil serving the padder
- One backhoe as required to supply the bulldozer as needed
- Four people involved in bedding and padding operations, and related restoration.
    - One padding/backfill inspector
    - One operator on the Ozzie
    - One operator for the backhoe
    - One operator for bulldozer
    - One site manager walking with equipment
- An inspector was available during bedding and padding, and backfill operations

Supports (Sandbags)

Although the contractor was different on this spread, practices associated with sandbag benches were similar to the Dynapad spread. Foam Benches were not used over any portion of this spread.

Breakers

As for the Dynapad spread, there was no opportunity to observe breakers during the limited time on the spread.

Bedding and Padding Operations

- The Ozzie Padder is an inclined in-line integrated loader and processor of spoil. It couples a single shaking or vibrating screen that is fed by a conveyer through a chute to a loader located at the front of the machine. The screen for this job had a clear spacing of about 2 inches on a side. As for Dynapad or any screen-based system, the incline angle of the screen coupled with movement of the screen and gravity controls the size of the material passing the screen, such that the material passed tends to be smaller than the clear pitch. These same parameters also cause the larger material to shift along the screen until for the Ozzie it is deposited on the shoulder of the ditch in the wake of the padder. The chute on the Ozzie lies behind an articulated "mouth" at the front of the machine that provides limited manipulation to broaden access and/or aid selection of backfill material. The machine operates on the shoulder of the ditch parallel to the pipe-string, feeding select fill to the pipe-string by a conveyer table that collects fines from the screen and delivers it to the ditch by extending the table from the machine toward the ditch. Because the spoil processor is in-line and integrated to its loader, access to spoil is controlled by the fines available from a linear track through the spoil windrow. For this reason, the spoil available in the windrow was enhanced by "roaching" the spoil using a bulldozer, adding material where possible and narrowing the windrow to better match the mouth of the padder. Very large rock several feet across was selectively removed during this process. However, in contrast to the feed to the Dynapad where large rock was selectively avoided by the backhoe operator, many quite rocks (some up to two feet across) remained in the windrow. This heavy-duty machine very efficiently separated these large rocks from the useful material in the spoil, conveniently dumped this unsuitable material in the wake of the machine. For this job the fines available from the spoil were forced a second pass and sometimes third pass to provide the specified bedding depth and padding cover. Because the machine very efficiently separates useful material from the spoil, little useful material remains after a pass through the windrow, leading to diminished returns from a second or third pass unless material is added to the windrow or the windrow reshaped with spoil that was not used on a prior pass. It follows that efficiency in padding is controlled by the length conveyer table, to facilitate access to spoil further from the ditch, and the amount of fines that are available from the windrow of spoil. Efficiency is also influenced by the quality of the ditching, as heavier versions of this machine must remain well off the edge of the ditch. For this job, the largest Ozzie was used, the weight of which kept it off the main spoil pile that during trenching was placed over two adjacent hot lines in the right-of-way. This too affected efficiency, as it limited the supply of available spoil. Other factors include the large diameter of

this pipeline and the uneven larger ditch due to the rock, both of which contribute to the amount to acceptable material required to meet company-specified cover.

- Bedding and padding reaching the pipe for the Ozzie appears to be homogenous in size and constituents throughout the cover. The cover appeared to be softer and more easily penetrated by large rocks that occasionally are placed over the cover as the ditch is backfilled.

- The size of the trench relative to the pipe was measured in several areas where the pipe had been lower-in. In some places the width of the ditch was more than two but much less than three times the diameter of the pipeline. This was wider than the minimum width based on company specifications, which based on discussions with help on-site typically required twelve inches more than the outside diameter of the pipe.
- Based on limited site observations, the Ozzie was used over stretches where rock was present. Forward progress was measured over several rocky stretches, which on average indicated the Ozzie produced 300 feet per hour. However, where multiple passes were needed, productivity dropped in proportion to the number of passes made. Where multiple passes were used, a backhoe occasionally was used to transfer spoil to the side of the ditch being padded. Where the spoil was rich in fines, cover from a single pass provided bedding, padding, and cover for the pipe-string to depths that reached one to two feet.
- Once the bedding and padding process had started, fill material off the screen flowed freely underneath the pipe, with little unfilled the area except below the invert. Continued flow of backfill appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void. The fines in the fill appeared to drop onto the already deposited material and remain in place, whereas the larger material rolled off these fines ahead of what remained close to the pipe, and into the ditch bottom. Consequently, while not inherently designed to produce layering of the deposited fill, in steady-state operation the coarser material "rolled" ahead of the fines to fill areas remote to the pipe, while fines remained near the pipe. However, such did not occur during startup when the generally uniform fill material fell or was projected off the conveyer table randomly onto the pipe. During this startup and over the first few feet of travel larger rocks that passed the screen could fall directly onto the pipe-string.
- During the startup phase, the fill material serving as bedding flowed freely underneath the pipe, with little unfilled the area except that below the invert. Continued flow of the fill material appeared to fully fill this area, and also compact the backfill by virtue of the weight of the overburden, leaving little of no discernable void.

- No tie-ins were done while on-site, so there was no way to observe how such areas were dealt with.

Backfill, Coating Condition, and Possible Damage

- Because of the limited preparation time, there was no opportunity to obtain jeeping equipment. However, the start-stop cycles associated with repositioning of the machine for a second or third pass, the contractor permitted brief entry into the ditch. This facilitated periodic evaluation of coating quality as well as the nature of the backfill. For this job the Ozzie worked the line of the lesser spoil piles laid on the side of the ditch away from the two hot pipelines, or occasionally from an elevation a several feet above the shoulder of the ditch, up to as much as about six feet for the operations observed. The screen's mesh size and conveyer table/gravity feed of fill material showed all material passing the screen impacted the pipe during startup of the bedding and padding operation. Thus, rock whose size approached the clear pitch of the screen contacted the pipe-string during startup, with occasional impacts occurring squarely at the crown. However, while not inherently designed to produce layering of the deposited fill, during steady-state operation the coarser material "rolled" ahead of the fines to fill areas remote to the pipe, while fines remained near the pipe. Industry experts associated with companies that sell or operate such equipment note this inherent property of the fill material as a key to the success of such equipment[e.g., 37,38,39,40]. However, during startup the rolling behavior does not occur. Instead, the generally uniform fill material falling or projected off the conveyer table randomly contacts the pipe. This was observed during startup and over the first few feet of travel, with the larger rocks that passed the screen fall directly onto the pipe-string, occasionally onto the crown of the pipe. It follows that little damage is anticipated during steady-state operation because the already present fines limit direct contact and the larger material rolls harmlessly down to the ditch bottom. However, damage might be anticipated during startup and the first few feet of the bedding and padding operation unless the spoil is roached selectively to limit this problem.
- Operators and personnel working with the Ozzie padder note that the richest zone of fines tend to lie toward the bottom and center of the spoil[39.40], such that an effort is made at startup to articulate the mouth of the padder into this area during the startup phase of the operation. Also during startup, this operator indicated damage can be limited by directing the flow from the conveyer table against the far wall of the ditch, filling that side with overflow onto the top of the pipe-string, followed by flow onto the now covered crown to fill the side adjacent the padder, such that the flow into the trench does not impact the pipe.
- Thus, operator "technique" gained through experience or training can be important to maximize the amount of fines available and limit damage during startup, whereas less is necessary during steady-state operation. This can be complicated by the fact that forward motion is needed to supply feed to the screen. As discussed for Dynapad, flow of the fill material forward along the pipe-string once the pipe-string is enveloped is controlled by soil mechanics through the angle of repose for the soil[36], which depends on the nature of the soil, including the size and to a lesser extent the shape of the fill material. Thus, any bedding and padding machine that satisfies these aspects should supply well compacted fill that flows around the pipeline, with the least chance for coating damage. Forward flow of the fill material and the natural selectivity for fines to precede coarser material down the slope created by the angle of repose has been

understood for decades as fundamental to success in bedding and padding[37,38], and a design parameter for such equipment. While an important parameter, whether or not damage is done depends on the resistance of the coating to impact and other forms of contact as well as the energy and the nature of the contact. Nevertheless, a machine that limits contact is a hedge to avoid coating damage. So long as adequate cover is developed over an initial section of the pipe, and subsequent fines flow forward and envelop the pipe, the fill added should cause no chipping or other coating damage. Success in this context is largely dependent on fill that flows freely, which occurs most easily for dry fine fill material.

- Physical inspection showed the steady-state layer deposited by the Ozzie was a mix of small stones and earth for this jobsite. The leading edge of the fines was loosely compacted, as was the material a foot or more back, in spite of additional material being overlaid. While physical inspection of the fill deposited over the crown of the pipe-string showed limited compaction, the weight of the eventual overburden deposited during final backfill and restoration is very likely to achieve high compaction. Because the operator recognized the importance of the startup phase to the quality of the fill material deposited during this phase, it was not possible to gain access to either the nature of this deposit, nor was it possible to observe the pipe's surface under conditions characterized by this aspect of the process. While unfortunate, the fact that this phase appears to be dependent on operator experience and skill suggests that such results, were they available, could not be generalized beyond the specific situation observed.
- Physical inspection where the fill over the crown of the pipe was removed was possible for steady-state operation at the conclusion of a padding run, or other stop-start cycle. Such examination showed a coating that looked as it did prior to the bedding and padding process, with no obvious evidence of nicks or chips.
- Padding material was not obtained for sampling at this site due to the limited time available to facilitate such studies.
- The depth of the padding developed is a clear function of the fraction of fines available and forward speed.

- While not specifically observed, the Ozzie operator indicated that upwards of 7500 feet could be covered over flat stretches during a typical day-long shift on a good day, and with a skilled bulldozer operator (that perhaps was supported by a backhoe operator). This claim cannot be substantiated and seems extreme, and is included here only for the sake of completeness.
- As for Dynapad, the opportunity existed to evaluate the Ozzie padding a short section running through a sag, where again because of the topography the spoil was wet. The screen appeared to be prone to clog, which slowed the process and limited the flow of fill material. Some clumping also was evident in the material deposited as it rolled down the leading face of the bedding and padding.
- As for Dynapad, areas where the ground was hilly revealed that the design of the Ozzie limits its motion to one direction. If it is going down a steep hill, there is the possibility of large rocks falling off the screen on top of the hopper and rolling past the padding operation onto bare pipe. This can be remedied through use machines working in opposite directions such that gravity causing large rocks to

roll back off the hopper would continue their movement toward already padded pipe. Such applies to all padders, becoming more acute as the incline angle of the padder increases.

Backfill Operations

- The backfill process was accomplished with a backhoe drawing fill material from the spoil piles. The padding appeared to have sufficient depth to preclude large rocks from reaching the crown of the pipe-string.
- A bulldozer was used top-off the trench after the backhoe was finished.

Site Two –Expansion (Kern River/Williams)

This project increased Kern River system's capacity by construction of a 36-inch diameter 740-mile-long looping through Wyoming, Utah, Nevada and California. The line pipe wall thickness varied as required for road crossings and class changes, consistent with class location and code requirements, and was coated with fusion-bonded epoxy whose. This construction parallels the existing mainline and was laid in that right-of-way. Four spreads were active during the period of the visit, starting with Spread 7 centered at Mesquite, Nevada, Spread 8 centered at Primm, Nevada, and Spreads 9 and 10 centered at Barstow, California. The right of way ranged from hard rock in some of the upstream areas, to sand in areas of California. Figure 3 presents a sequence of photographs that capture features along the right-of-way, from the ditching through the construction and restoration for this project. Further description of the site can be found in the body of the report. The field report follows verbatim as filed.

<u>Spread 7:</u>

36-inch diameter with 0.429-inch wall and factory-applied brown-coat FBE. This pipe was laid in a largely machine ditched trench, although some short sections involved shot rock.

Equipment (padding operation)

- Three Ozzie padders – Two model 200, one model 300
- Two Outlaw padders (support)
- One auger dozer (backfill)
- Two bulldozers (backfill and roaching)
- Approximately 14 people involved in this aspect of operation

Equipment (lowering in)

- Four side booms

Equipment (other)

- One paddle hoe (backfill for leveling later by bulldozers)
- Numerous small water trucks (counted 8 at one time; others in route returning and leaving, several large water trucks - Clark County requirement for dust control)
- One foam truck – crew of 3, technician (company), foamer and driver (contract)

Inspectors

- There was one inspector present at padding operation, but could not identify inspector at lowering-in for certain.
- Two FERC representatives and one Environmental representative (which were readily identifiable from other personnel on site)
- One green hat (biological monitor) focused on ground turtles and their habitat in areas of equipment operation, with several walking the right of way between operations.

Supports (Foam Benches Only)

- Polyurethane foam (two-part) supplied by subcontractor Pedero Pipe Support Systems (Alberta, Canada) www.pedero.com .
- Spacing was approximately 18 feet (paced by operator), with height ~18 inches, width ~12 inches, and length equal to the width of trench. The height and width approximate and variable, as the benches were spray-formed from top of trench.
- Discussion with technician of one truck indicated they can spray-form benches for an average of two miles per day – comprising approximately 590 benches at 18' spacing. Analysis of this rate suggests this estimate is high, as it corresponds to a bench per minute for a 10-hour day. This does not allow time to change supply barrels and seemed faster than the observed production rate evident over a brief observation period.
- Discussion with Peter Ellis (Operations Manager and son of company President) indicated the following facts:
    - Two basic types: open cell and closed cell. Closed cell much better, open cell structure is more porous/pervious.
    - Foam temperature due to exothermic chemical reaction was approximately 175°F.
    - The foam "solidifies" in seconds, with strength developed over its cure time, which was 1 to 2 hours.
    - The design density was set at 2.2 lbs/ft^3, leading to great compressive strength (although localized failures evident from time to time suggests otherwise). Design density is based solely on diameter/wall thickness (weight) of pipe.
    - Decomposes under UV light (sunlight) and water saturation (reference to breakers), but this occurs over a great deal of time. Discoloration of outer surface almost immediate, which was explained as being caused by sunlight.
    - Density can be altered by design, but not at site as the chemical makeup for this property is established and then batched into barrels at the home plant, from where the material is trucked to the jobsite.
    - Although the benches (pillows) can be sprayed from trench top, pre-made or shot into plastic/tarp bags, this job used in-situ sprayed benches.
    - This spread also used sprayed foam as a reverse rock shield, as a layer of foam up to a few inches thick was sprayed up the rock on the trench wall opposite the side from where the pipe was strung.

Lowering-in with relation to benches and reverse rock shield

- In a flat straight pipe runs, most cases showed the benches supporting the pipe uniformly and with moderate compression in the vicinity of the support.
- Where changes in direction occurred, not one case was observed where all benches through the curve were uniformly compressed. Spans existed where one or two benches showed little evidence of compression, and so carried little pipe weight. This caused the benches either side to be severely compressed. Potential causes for this include:
    - Bench heights not uniform from one to the next
    - Bench heights not uniform along its own length, therefore pipe curvature not matching trench curvature will rest on different parts of bench, not always centered.

- As these same potential causes can lead to problems in the straight sections, whereas none existed that were so obvious, other potential causes are more likely responsible for the problems. More likely causes include:
    - Problems in matching the bend orientation to the ditch profile, and,
    - Problems in making tie-in welds.
- Similar difficulties existed at sag-bends and over-bends, where again not one case showed adjacent benches were uniformly loaded. Problems here were more severe than for changes in horizontal direction, as spans of three benches were evident, as was nearly complete crushing of the bench preceding this span. Again excluding causes shared for straight runs, likely causes include:
    - Pipe elevation change not matching trench elevation change,
    - Problems in making tie-in welds.
- In several instances, the pipe had to be raised up in sections that involved turns and elevation changes. It clearly shows (from the photographs) how the foam is unable to handle the pipe load if spans exist. This is pipe weight alone, BEFORE it is bedded, or backfilled, or water is introduced into pipe for hydrostatic testing.

- In one section coming over a hilltop, the pipe was not centered properly and a section of trench wall was not flush (had a slight protrusion) causing pipe to initially get hung up. In this section, foam was sprayed about a third of the way up wall to help with abrasion

in a narrow section. Pipe hit at top and scraped on the way down. By the time it got to foam on sidewall it was centered. Foam in this type of situation should be sprayed ALL the way up the side of trench wall.

Additional Observations for Lowering-In

- Contractor opinion was that the foam benches were much quicker and less manpower intensive than more traditional sandbag method.
- The bench crew was found to be much faster than pipe could be lowered in, as this crew was miles ahead of the lowering-in operation.
- On spreads with significant hills and valleys, causing pipe to be strung and joined into many sections, the rather tedious process of tie-in welds appeared to dictate construction progress, with other issues apparently secondary drivers for completion of the spread.

Bedding and Padding Operation

- Three Ozzie padders were on-site, with a larger 300 model working in front of smaller 200 models. A double tandem scheme was common, with the third smaller padder available as backup for double tandem use, or for use in a triple tandem, or for dealing with tie-ins and other specialty areas. Each Ozzie had a single screen with a clear pitch passing one-inch aggregate per company specifications.
- Extremes of pipe height over trench floor ranged from ~4 inches up to ~16 inches. Randomly chosen measurement sites indicated heights of 10, 8, 9, 12 and 7 inches.
- Size of the ditch relative to pipe was varied depending on type of soil and whether a turn was involved. Straight sections and areas through soft rock made by a "wheel" hoe trenching machine produced a fairly consistent width of 4 feet, which satisfied required minimum width of twelve inches greater than outside diameter of the pipe. A few short straight sections were apparently done by a backhoe and were about five feet across. Areas through turns and areas that were greater shot were much wider than this. Often the width at the top of the ditch was many times the diameter of the line pipe.
- The rate of progress varied relative to spoil and trench width and depth. For example, 1 hour and 15 minutes was taken to cover a 0.2 mile long stretch through a wide turn. In contrast, the same amount of time was needed to cover a 0.6 mile long straight stretch using one padder along ditch that was consistently four feet wide. Another similar stretch of 0.9 miles took 4 hours to complete.
- Where the three Ozzie padders worked in triple tandem, three bedding and padding passes could be accomplished in the time required for one, without the need to backtrack to affect the required coverage. Because the spoil pile created by machine ditching was almost all fines, there was no problem in fines supply through these areas. At times, the rear padder would back up a bit to cover a particular section that the pipe was higher off the trench floor or where the spoil was heavy in larger rock content, necessitating more frequent passes to develop adequate bedding and padding cover.
- In observing extent of fill once both sides of the pipe were padded, coverage looked complete, as the fill extracted from the spoil was fine enough to flow in and leave no observable voids.
- The depth of padding above the pipe averaged in the range of 12 to 18 inches.

- Padding material was obtained with a total of four samples, with the laboratory analysis included in Appendix C.
- Because the padding sequence involved all vehicles working linearly in a tight formation, no jeeping was possible as the pipe was fully covered in one pass, without access to areas available during start-stop cycles, or the period where the padder was repositioned for a second or third pass.

Additional Observations for Bedding and Padding

- During stretches where there were large rocks present in spoil and the spoil height was large, quite large rocks were occasionally knocked onto the pipe by the action of the padders. While the crew included laborers working along the ditch to intercept such rocks and thereby limit damage to the pipe, from time to time the rocks were too large to be stopped by the two-man shovel crew assigned this task. In such cases, the string of padders would stop and the assisting crew would patch the pipe with a thick application of two-part epoxy, covered by a tape-over, so bedding and padding could resume without concern for the cure time or the possibility padding material would move the patch or adhere to it when they resumed. At least five such patching operations were observed in a day-long shift.
- At one point, a section that was covered with at least 12" of padding was hit by a large rock that rolled down the spoil pile. The cover displaced somewhat, but this large and heavy rock did not come close to contacting the line pipe's surface.
- In severe to extreme rock conditions, as occurred with shot rock, the padders were supplied by bulldozers that roached the windrow to supply adequate padding material.
- One short ring of pipe discarded from a tie-in provided the opportunity to assess the sensitivity of the brown-coat FBE to contact with rock. While not scientific, these ad hoc experiments using small rocks located in the right-of-way provide insight into the resistance of this coating to impact and scraping. The results of these impacts and scrapes showed this coating to be quite resistant to damage, at least at the moderate daytime temperatures of southern Nevada during February when it was in the high 60s (°F). More formal evaluation of coating damage resistance under parametric contact conditions would develop a quantitative understanding of what contact conditions are problematic, and facilitate developing value-based (performance) specifications to maximize safety in concert with productivity.

Backfill Operations

- Immediately following the padders, an auger dozer and two bulldozers performed the backfill operation. From the previous additional observation stating the large rock falling on the padding, I believe the backfilling procedure would not be capable of having larger rocks contacting or coming into close contact with the pipe.
- A "paddle" hoe was behind the backfill operation pulling dirt from the original spoil for subsequent leveling at a later time.
- Inspector was present for backfill operation.

Spread 8

36-inch diameter with 0.429-inch wall and factory-applied brown-coat FBE. This pipe was laid in a largely machine ditched trench, although some short sections involved shot rock.

Equipment (padding operation – several locations noted)

- Four Ozzie padders – two model 200's, two model 300's
- Two Outlaw padders
- Two bulldozers (backfill and roaching)
- Approximately 16 people involved in this aspect of operation

Equipment (lowering in)

- Four side booms

Equipment (other)

- One paddle hoe (moved backfill for leveling later by bulldozers)
- Numerous small water trucks (required for dust control)
- Two foam trucks – crew of 3, technician (company), foamer and driver (both contract employees), and Peter Ellis (Company Operations Manager)

Inspectors

- There were several inspectors present at padding operation – but unable to track and identify the exact number.
- One FERC Representative and one Enviromental inspector (that were readily identifiable through casual observations).
- Green hat biology monitors focused on ground turtles and their habitat in areas where heavy equipment was operating and walking the right of way between operations.

Supports (benches)

  - See discussion for Spread 7

Additional Observations for Supports

- A couple of sections used dirt as the material for the benches. When an inquiry was made into this, the reply from Peter Ellis indicated an agreement was reached to allow this because the site boss did not want to lay anybody off, so a make-work job involving benches was created. Williams Pipeline indicated the dirt benches comprised approximately 15 percent of the total, presumably over the length of the spread.

Breakers

- Like the benches, breakers were made using sprayed-in place polyurethane foam.

- These were approximately one foot across at the top tapering out to approximately two feet at their base.
- Several breakers were observed with vertical and horizontal splits in the top section (photographed). While one inspector mentioned the Pedero personnel would make needed repairs, this was never observed.

- Pedero's website provides reference information and photographs typical of their supports and breakers. Their photographs showed tightly grouped breakers, which are more closely spaced than breakers installed at this site. However, ditch stabilization needed depends on many factors, such that direct comment on this aspect absent more detail is inappropriate.

Observations of lowering-in with relation to benches

Comments for spread 7 apply here

Additional Observations on Supports

- There were some benches that seemed less robust as compared to those found in Spread 7, some of which did not run the full width of the ditch. While this looks bad, such is the case for pre-formed foam benches, and it is only problematic when the bench fails to support the pipe.

Bedding and Padding Operations

- Notes for Spread 7 apply here, with the following differences.
- Four Ozzie padders were used, with two 300 models and two 200 models involved. These padders tended to work independently, which required each padder to make several passes through roached spoil to attain the required bedding and padding cover. The 200 model Ozzie tended to need three passes to achieve this. When a 300-model padder worked in tandem following a 200-model, the number of passes was reduced to two (i.e., one combined double pass).
- Where the 200-model padder was used independently, the first two passes impacted the pipe, first filling first one side over the crown and then the second side. The third pass supply cover across the full width of the pipe, with cover depths ranging from 18 to 24 inches.
- Limited straight runs where ditched by backhoe were up to six feet across. In general, ditches in the vicinity of turns and areas involving shot rock were wider as compared to Spread 7.
- Forward progress on this spread was difficult to assess, as the several padders on this spread generally worked independent of each other. Accordingly, total forward progress was assessed by considering the padding accomplished by all four padders, which was estimated at about four miles over a three-day period for four padders, giving about a mile per 10-hour shift per padder.
- Padding material typical of that involved was obtained for three samples, with the laboratory report included in Appendix C.
- Because the padding technique involved a start-stop cycle where padders were repositioned for a second or third pass, it was possible to enter the ditch to jeep on two occasions. This was done by driving a four foot copper rod into the ground above the trench. A grounding wire from the portable jeep was connected to this and then thrown into the trenching location. Jeeping was done by climbing down a breaker and then walking the ditch. The first location involved a length of about 32 feet, which comprised the length of the grounding wire in both directions from copper rod. One coating nick

exposing metal was found at approximately the 11 o'clock position, which was about ¼ inch in diameter. This large chip was likely due to larger rock that rolled down the spoil pipe that was not repaired, as no evidence of similar features were found along the 32 ft measured. The second stretch jeeped was approximately 100' in length, in a process aided by a top-side laborer that removing and reset the copper rod over this length of pipe. This jeeping failed to indicate nicks in the coating over this stretch. In both cases, this jeeping reflects steady-state operation.

Additional Observations of Bedding and Padding

- Two Outlaw padders were also used as bedding and padding in this spread. These were used specifically for runs involving a very steep grade and at tie-ins that had been bypassed by the Ozzie padders. Based on limited operations and crew comments, these machines appear to be slower than an Ozzie mainly because of their loading design. A bulldozer that roached spoil supported these padders, whose use involved a crew of four. (One Outlaw was broken-down during our time on site, which limited observations.)

- Cover achieved by the Outlaw ranged in 18-24" in depth.
- As was observed for Market Link, the observations indicated operator skill or technique is important for the Ozzie padder, as the observations here indicated the only time the spoil is directly hitting the pipe is during startup. It was noted that the operator works the spoil to fill the ditch at startup, after which spoil flows out across the top of the pipe then begins to proceed forward along the pipe-string. In this approach, spoil coming off the conveyor only hits the pipe during the initial fill, with operation later dropping fill material onto already existing fill that then flows out over the pipe. This provides a couple of inches of fill cushion that can cushion the fall of the 1-inch or smaller aggregate used, and limit damage to the coating.
- At one time, a rock approximately nine inches across fell onto shallow cover on pipe. The person walking alongside the padder went in and pushed it to the side, without visual inspection. Such behavior likely reflects experience that damage is not typically

experienced for the cover present and the size rock involved, as other similar scenarios on Spread 7 that led to small chips and coating repair tended to occur with contact to unpadded or sparsely padded pipe. In contrast to Spread 7, for this spread the two-part epoxy patching used on Spread 7 was never observed, which suggests the quality of the final product is dependent on the crew as well as the equipment used to bed and pad the pipe.

Backfill Operations

- There were long stretches of padding done without any backfilling being done. When observed, it involved one bulldozer pushing in backfill to restore the grade.
- A "paddle" hoe was present for later leveling purposes but this observation was not witnessed in real time.
- Not sure if there was an inspector present for backfill operation.

Spread 9

Work finished on this spread in the week before our visit. Its topography and geography looked similar to Spread 10.

Spread 10

36-inch diameter with 0.429-inch wall and factory-applied brown-coat FBE. This pipe was laid in a trench dug either by a ditching machine or a backhoe through relatively soft sandy soil.

- This spread was flat for most of its distance and the soil contents were fine akin to sand.
- No padders were apparent, although the crew indicated there might have been one somewhere on this spread.
- There was no padding evident. The fill operation was completed by a bulldozer that moved fine spoil back into the trench.
- No benches of any kind were used here, the pipe was just laid in the trench although they did water compact the floor of the trench.
- Some stretches of trench were cut out using the "wheel" hoe (trenching machine), while other sections used a backhoe.
- The trenches were about 5' wide by 8' deep where the "wheel" hoe was used and wider when a backhoe was used.

Lessons learned for subsequent site visits

- When booking hotels for different spreads, getting one near where the actual work is being done on the spread versus where their offices are would significantly cut down on travel time and allow more time to be spent at the site itself.
- Some sort of compact/collapsible ladder would greatly increase ability to enter the trenches for jeeping tests. This allows quick/safe entry and exit and the ability move copper rod for longer jeeping runs.

- Acquire a longer grounding wire for jeep to increase distance of jeeping before having to replace copper rod.
- Bring a broom to quickly sweep off spoil from top of pipe to alleviate using hands/jeep paddle to remove dirt.
- Research applicable regulations for entering a trench to aid in ability to conduct tests.
- If spoil is kept wet by water trucks, compaction test is unnecessary.
- Voice recorder would increase frequency and detail of notes taken in field versus journal
- Ground markers of some sort to more accurately mark locations for distance covered by padders during a time period (hours/day, etc.). If the terrain is flat and free of landmarks, once the equipment is moved and pipe has been backfilled it can be difficult to relocate the exact stop-start locations, especially several days later.

Site Three – Patriot (Duke)

The Patriot project is part of the construction underway as part of the East Tennessee Gas Project (owned by Duke Energy). Multiple spreads were working between Tennessee, centered near Bristol, and Virginia, centered near Wytheville. The construction involved 24-inch diameter line pipe whose wall thickness varied as required for road crossings and class changes, consistent with class location and code requirements. This line pipe was coated with polyethylene tape. Figure 4 presents a sequence of photographs that capture features along the right-of-way, from the ditching through the construction and restoration for this project. Further description of the site can be found in the body of the report. The field report follows verbatim as filed.

Line Pipe - 24”with wall thickness of 0.429” covered by tapecoat.

Equipment (padding operation)

- One Dynapad padder
- Two backhoes (both as padders and/or as backfill)
- One bulldozer
- Nine people involved in this aspect of operation
    - Two padding/backfill inspectors
    - One operator on Dynapad
    - One operator each for backhoes
    - One operator for bulldozer
    - One Dynapad padding assistant walking with equipment
    - One laborer per backhoe

Equipment (lowering in)

- Four side-booms (three shown, one holding up pipe at tie-in)

- One long sandbag truck (benches) – driver, 4 laborers (two on truck, two in trench) and foreman. They were a bit ahead of lowering in crew
- One Bulldozer
- One Marachi – halftrack vehicle with supplementary sandbags, ladders, miscellaneous equipment etc.

Equipment (other)

- One long sandbag truck – driver, 4-6 laborers and foreman (breakers)

- One metal skid for skids (dragged by a bulldozer)
- One bucket-type hoe, one clamshell hoe (dredging trench in front of lowering-in and behind jeepers and coating crew)

Inspectors

- Two for padding and backfill operations

Supports (benches)

- The typical number of sandbags varied from support to support, ranging from three to six in the sandy soil areas but predominantly three were used. Higher numbers of sandbags was used in instances where rises, sags, and turns were prevalent to accommodate pipe bends not exactly following the trench elevation contours or radius of turn and in the stretches containing rocky soil. Also, road tie-ins used an increased number of sandbags.
- The center-to-center distances varied widely with the terrain. One particular stretch yielded center-to-center distances of 10.5, 9, 17.5, 17, 15, 30, 6, and 20 feet. Only in very rocky and hilly sections were they relatively consistent,

averaging six to ten feet. The specifications called for sandbag spacing to be approximately fifteen feet apart.

- Foreman was unaware of the cost of the sandbags.

Additional Observations for Supports

- One truck was positioned ahead of the lowering-in crew that was busy setting the sandbags for the benches. The first two days on site involved terrain that was sandy and rocky in stretches. When the soil was consisting mostly of fines, a few sandbags were separated by larger distances, while in other places the pipe simply laid on the trench floor. In the rocky stretches, the sandbag count and frequency increased to match the terrain.
- Differences in terrain led to apparently inconsistent arrangement of the sandbags. In some cases they were laid in what looked like a hasty manner. Where three or fewer sandbags were used, their use seemed less functional, as occasionally they did not keep the pipe of off the trench floor. However, as just noted this tended to occur where rock was absent, and so was not consequential. No attempt by the padding crew was made to adjust any pipe supports that otherwise might have not appeared sufficient.

Breakers

- The breakers at this spread were constructed using sandbags.
- The typical number of sandbags required for a normal sized breaker is approximately 225. The foreman stated that it would take approximately 30 minutes for a crew of four to construct this, which seems a viable estimate. The largest breaker observed contained over 900 sandbags.
- Typical breaker dimensions were 15 inches wide, stopping about one foot below the top of the trench.

- The breakers appeared to be well constructed and uniform.

Observations of lowering-in with relation to benches

- Lowering-in involved four side booms with at least two laborers or lead hands walking along side. The person walking in the back was responsible for keeping the pipe either centered in the trench or on the benches if present. The section where lowering-in was occurring typically involved a flat rock-free trench where the pipe was laid directly on the trench floor, with no sandbags involved as is usual for such trench bottoms.
- This particular section of the spread was fully strung and the pipe joints welded, except for road tie-ins, as compared to other spreads where the jointed pipe was much more segmented and so involved more tie-ins.
- Sandbag footprints varied greatly. The sandbags themselves were in the 10 by 15 inch range, with a footprint consisting of a 10 inches by 30 inches.
- There were several instances of the pipe not resting on the benches with the greatest span being five benches bypassed with no contact, as evident in the next photograph. A significant portion of the pipe observed contained few to no sandbags due to the soil content consisting mostly of fine material with little to no rocks present. However, it can be anticipated that elasticity in the pipe string and compression in the benches will facilitate eventual settling onto the bedding.

Additional Observations for Lowering-In

- There was an instance where a side-boom slipped off the edge of an area of stepped ditch, which knocked the pipe off of the skids and into the trench. Approximately 1500 feet went into the trench. When the pipe was raised out and inspected, there were two dents requiring cutouts and numerous divots in the coating that also required repairs.

Observations of Bedding and Padding Operations

- The Dynapad was used throughout
- See discussion of Dynapad padder presented in the section on Market Link – Dynapad Spread for details of the operation and overall strengths and weaknesses of this padder, which apply equally here, and are reinforced as noted by observations specific to this spread.

- As for Market Link, Dynapad provided a layer of fines about 12 inches deep on average, followed by a small rock layer and thereafter larger rocks.

- In most trench areas where the soil was fine without rock content, the pipe was laid directly on the trench floor. Occasionally in these types of area, stacks of three sandbags were used as supports, being spaced along the pipe-string at quite large distances. These appeared to have little to no impact on the clearance between the trench and the pipe, as 1 to 2 inch spacing or more was found in some places where at other sites the pipe rested on the ditch bottom.
- In rocky areas where more sandbags were used and spaced more closely together, the supports developed the required offset, as clearances there measured at random sites ranged from 22 inches to as little as four inches, but more typically were in excess of 10 inches, while the specifications targeted eight inches.
- The size of the trench relative to the pipe was measured in several sites. These measurements indicated trench widths from the order of four feet up to seven feet, with depths from seven to more than 9 feet. Trench width easily met the required minimum width of twelve inches greater than the outside diameter of the pipe, with eighteen inches required when there is rock in the ditch or water crossings (creeks, streams, rivers) are involved. Likewise, the depth easily met the specified minimum that required a minimum cover of thirty-six inches for stretches not involving railroads, highways, water crossings etc. This equates to a minimum depth (clearance + pipe diameter + minimum cover) of 5feet- 8 inches, whereas the depth as measured was typically greater than seven feet.
- The nature of the ditch at the time of observation involved short stretches where rock was present interspersed in long stretches where few to no rock was present. The padder was used of the short rocky stretches, while the remainder was padded with backhoes from the spoil pile.
- Two short rocky stretches were timed with the Dynapad covering 175 feet in 30 minutes for one stretch and 217 feet in 20 minutes for the second stretch. The combination of the fines, two layers of small rock and spoil spilling over the back of the hopper as it is being loaded from the backhoe affected coverage of at least two feet with upwards of three feet.
- In observing the extent of the fill under the pipe, the material flowed freely underneath and filled the area underneath with no discernable voids.

- The padding operation involved one Dynapad padder, two backhoes and one bulldozer with a total of seven personnel (equipment operators, one inspector, two laborers). There was another padder on site, but it was relegated to mopping of tie-ins and other spot areas.
- Because backfill via backhoe immediately followed the bedding and padding process, there was no start-stop cycle to admit jeeping the pipe for nicks in the coating. But as noted previously, the design of this machine layers fines adjacent the pipe with increasingly larger material away from the pipe, which limits the chance of rock contact and so virtually precludes rock damage.
- Padding material was obtained with one sample from an area consistent with most in the area of observation. The laboratory soils report is in Appendix D.

Additional Observations for Bedding and Padding

- The depth of the padding coupled with the double layering of different sized rocks was sufficient to keep large rocks coming off the back of the hopper and from backfill operations from impacting the pipe.

- The operator for the Dynapad stated that on a good day with the backhoe operator keeping up he was capable of doing about 9000' over flat stretches. However, this estimate cannot be verified in reference to the data gathered from this site, which at best indicated 651 feet per hour or about 6510 feet in a 10-hour long shift.
- Where the spoil is wet, the same problems evident in limited observations for Market Link were again apparent. There was some evidence of blockage that slowed progress, and the fines were prone to clumping that becomes evident from the start of processing the wet spoil. The design of the hopper area on a Dynapad also appeared susceptible to clogged from roots and other debris in the spoil pile. If roots were left to build up enough, it was remarked that they would need to be burned out.
- Finally, as noted for the Market Link Spread, the design of the Dynapad limits its motion to one direction, which will be a problem for any machine, becoming more acute as the incline angle increases. This can be remedied by running in a direction that causes large rocks rolling back down to do so onto already padded pipe.
- In some places (sags), standing water was not pumped out.

Backfill Operations

- The backfill process was accomplished with a backhoe with fill material obtained predominantly from the spoil pile.
- The padding appeared to be of sufficient depth that any large rocks from the backfill would not come in contact with the pipe.
- A bulldozer was used to top-off the trench after the backhoe was finished.
- An inspector was present for all backfill operations.

Additional Observations for Backfilling

- There were times especially near tie-in areas where a backhoe was used for padding when the spoil contained significant rock. I noticed on several occasions where large rocks fell on the pipe in these instances. As such, overall coating quality is controlled by much more than the bedding and padding machine used over most of the job.
- The bucket from the backhoe was used occasionally for compaction after the backfill was deposited.

Site Four – Cardinal (Marathon)

The Cardinal Pipeline construction runs through spreads from near Columbus Ohio south toward the Ohio – Kentucky border. This hazardous-liquid pipeline was constructed from 14-inch diameter line pipe with wall thickness that as usual varies as required for road crossings and class changes, consistent with class location and code requirements. The line pipe was coated with thin-film FBE. Figure 5 presents a sequence of photographs that capture features along the right-of-way, from the ditching through the construction and restoration for this project. Further description of the site can be found in the body of the report. The field report follows verbatim as filed.

Pipe size - 14", Wall thickness - 0.25", using a mix of green or grey thin-film FBE

Equipment (padding operation)

- One Ozzie padder – model 200

- Two backhoes (one backfill, one roaching)
- One bulldozer
- Nine people were involved in this aspect of operation
    - One padding inspector
    - Two operators on Ozzie (one local, one Canadian District Manager learning operation of equipment)
    - One operator each for backhoes and bulldozer
    - One Ozzie padding assistant walking with equipment
    - Three laborers

Equipment (lowering in)

- Three side booms

Equipment (other)

- One foam truck – crew of three, technician, foamer and driver (OJS Company, which is Offshore Joint Services)
- One skid truck
- One bulldozer

Inspectors

- One inspector was present for padding and backfill operations.

Supports (benches)

- Polyurethane foam was initially used at this site but was discontinued before my arrival. Its use was stopped subject to procedural requirements.
- Sandbags were used while I was there but was told that they would probably be going back to foam benches at a later point.
- The typical number of sandbags per support was five, ranging from four to seven. In some cases, more sandbags were used in instances where rises and sags were prevalent, to accommodate pipe bends not exactly following the trench elevation contours. Also, a greater number of sandbags were used at all tie-in locations due to a deeper trench being dug at these locations.
- Sandbag count along a typical stretch indicated the number involved was 5, 5, 5, 7, 7, 5, 6, 5 and finally 5 again.
- Typical configuration of a five sandbag arrangement was two abreast; two abreast above that and the fifth sandbag straddling center position on top.

- The sandbags were bought from a local company at a $1.25 a piece. Trucks would drive the right-of-way depositing sandbags for benches, which per comment on site was to occur every twenty feet. The lowering in crew would place the sand bags as they proceeded. Extra bags were to be available where needed. I did not witness this, but estimate from prior observations at other sites two people were placing bags in trenches for supports.

- In one stretch, the distances between successive sandbag placements were as follows: 18.5’, 16’, 19’, 18.5’, 20.5’, 12’, 19.5’ and 16’. Another shorter stretch showed spacing at 16.5’, 17.5’ and 18.75’.

Additional Observations for Supports

- It was stated that the placement of the sandbag supports was to be every 20’. The measurements indicated that the majority of the distances came in under this distance. This in turn will decrease the load per bench and help decrease the possibility of ovalization or denting of the pipe.

Breakers

- Open cell polyurethane foam was used, which allows the passage of water, was used for the breakers. The company providing this service was OJS

- Technician stated that foam temperature reached 135 degrees during curing. The technician was unable to provide density or compressive capacity.
- Typical breaker dimensions were 12 inches wide and 4 feet to 4.5 feet high.

- They were spaced using the following company specifications: for slopes at 5-15 degrees space at 300 feet apart, from 15-30 degrees space at 200 feet apart and over 30 degrees space at 100 feet.

Additional Observations on Supports

- There was no evidence of splitting in the breakers was seen once or twice at Kern River. The one split observed on the Cardinal spreads was caused by the raising of the pipe to add additional sandbags at one location.

Lowering-in with relation to benches

- The lowering-in was done well ahead of the padding crew so this could not be easily observed given the project's focus was bedding and padding. It was however apparent that the pipe-strings that were jointed were quite segmented, driven apparently by the topography and routing, which led to many rises and sags, some of which were quite steep. The tie-ins at roads crossed (there were many in the stretch I attended) were not completed. There were also many portions along the route that were not yet welded. .
- A typical sandbag footprint was the order of 15 inches by 36 inches.
- A rough estimate indicates that at least 95% of the pipe was properly seated on the benches. Only \a few instances were observed where there was space between support and pipe and it was never more than one bench in span. However, this is likely to change as tie-in welds are completed. The inspector indicated that on several occasions he had the pipe lifted to adjust bench height, although such permits only coarse adjustments if it was done. Accordingly, the absence of tie-in welds is the most likely reason for this high frequency of well-seated pipe.

Bedding and Padding Operations

- The padding operation involved one Ozzie 200 model padder, two backhoes and one bulldozer accompanied by nine personnel. There was another padder on site but it was relegated to mopping up of tie-ins and other spot areas.
- The Ozzie's screen pitch for this job was two inches by two inches.
- A majority of the time, the fines being introduced from the padder into the trench was not impacting the pipe. The flow was directed by the operator to hit in between the pipe and the trench wall. On subsequent passes for the same side of the pipe, the fines would spill over the top of the pipe and then the other side of the pipe would be padded. The final passes would meet the required cover over the pipe.
- Along a joint of pipe, clearance heights from bottom of pipe to trench floor were 9, 11, 13, 18, 12, 9 and 11 inches, while random locations showed clearance heights of 10, 12, 10, 9 and 14 inches. The largest clearance measured was 19 inches, although inaccessible locations such as near tie-ins showed even larger clearance.
- The typical ditch width was 5 feet wide, with the narrowest being 3 feet-8 inches. The typical ditch depth was 6 feet, with slightly deeper instances measured. The specifications for a 14 inch diameter pipeline require a minimum trench width of 30 inches and a minimum trench depth of 56 inches (clearance + pipe diameter + minimum cover) in areas other than industrial, commercial, residential, crossing of inland bodies of water, and public roads and railroad drainage ditches.
- The rate of progress for the Ozzie varied widely depending on the fill circumstances encountered. For example, a one-day shift on one occasion covered about 600 to 700 feet, while this same period on another day covered about 2400 feet. Often the terrain was hilly and muddy, which hampered forward progress.
- The number of passes required to achieve the required bedding and padding cover varied as is expected. A minimum of three was required to obtain the proper cover, with as many as six required in the worst case. The high number of machine passes was necessary due to the extent of mud prevalent at the site. The wet and clumped dirt/mud coated the screen and did not pass easily through the screen. The required cover was 6 inches, with the padding applied easily exceeding this requirement. The cover thickness ranged from 8 to 12 inches typically, and sometimes was even deeper.
- The extent of the fill under the pipe was as for cases where the spoil was dry, evidently because the fill material that easily passed the screen had properties comparable to cases where all fill material was dry. The fill flowed freely below the pipe and filled the area underneath with no discernable voids.

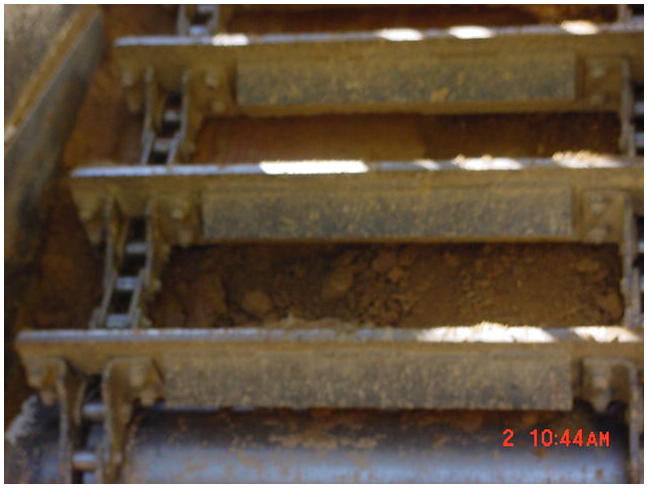
- While the majority of the time, the fines introduced from the padder was directed by the operator to hit in between the pipe and the trench wall, there were instances of the padding material landing on the crown of the pipe. Such occurred for a short stretches as the operator redirected the flow. When the operator was traveling over a double-stepped dich shoulder, which was necessitated due to the contours of the hill and the direction of pipe travel, the likelihood of hitting the pipe was much more prevalent. Jeeping was done whenever possible for such scenarios, but these opportunities were constrained by safe entry to the trench. Entry had to be performed at the foam breakers due to trench depth. Also, if breaker was too far from point of interest, too little time was available to get into the ditch, perform the jeeping, and then get out without inhibiting padder progress. About 400 of such padding operations were jeeped, with only one instance chipped coating identified. This chip was found where fill material from a two inch square clear screen pitch fell directly onto the crown of the pipe. Small regions of chipped coating are easily dealt with by the cathodic protection system. Nevertheless, such chips reflect reduced coating quality as compared to a pipe-string installed free of such features.

- Padding material was obtained for three samples, the laboratory report for which is reported in Appendix D.

Additional Observations for Bedding and Padding

- One of the main factors controlling progress for the Ozzie was the extreme muddiness. A second key factor was the fact that the right-of-way was only 50 feet wide, which allowed space for only the trench and one lane. This appeared to cause several problems:
    - If any equipment had to get in front of or behind someone else for any reason, everyone had to move out for the others to get in and then the procedure was reversed to get back to original orientation.
    - During the period observed, the Ozzie could not work the spoil pile so it was getting its padding supply from a backhoe roaching the adjacent right-of-way.

- The Ozzie, like any screen-based system, does not handle extreme muddiness very well. In addition to slowing progress, dealing with the mud required a twice per day cleaning that required 3 to 4 people and led to 1½ hours downtime twice per day. Mud was observed to buildup underneath the conveyor belt and chain to thickness up to about 5 inches, which was so compacted that its removal required it be chipped away with a shovel.



- One possible concern associated with any padding machine was occasionally evident where the cover was observed to take on the shape of the pipe, or form a crown over the centerline where the cover is deeper than on either side. Where the depth is minimal and measured over the centerline there is a change the flanks are not adequately covered. Moreover, there is a tendency for larger material placed over the cover during backfill to fall toward the space between the pipe and ditch wall, possibly wedging into such areas, or enabling large rocks to be resting closer than desired to the pipe-string.

Backfill Operations

- The backfill process was accomplished with a backhoe drawing from the spoil pile when it could be reached, or from fill material lying on either side of the right-of-way.
- The padding appeared to be of sufficient depth to keep any large rocks entering the ditch during backfill from contacting the pipe when deposited by the backhoe.
- A bulldozer topped-off the trench after the backhoe was finished.
- An inspector was present for all backfill operations.

Additional Observations on Backfilling

- The bottom of the bucket on the backhoe was used for compaction, which could cause movement of larger rocks.
- As is the case in general, where the ditch is unstable large rocks deposited during the backfill process could move through the cover and padding possibly negating their function.

Site Five – Expansion (Colonial)

Construction of the Colonial expansion runs through portions of Tennessee with topography and geology similar to that of the Cardinal Pipeline. Because this construction was concurrent in time with the Patriot project and also ran through Tennessee, these multiple spreads could be accomplished through one visit. This construction used Ozzie padders through similar conditions as the Patriot construction done using Dynapad, which made this a potentially useful site. These spreads involved soils of mixed clay and rock through quite hilly terrain. Unfortunately, the construction did not present enough rock to necessitate much use of bedding and padding equipment, nor was there much opportunity to significantly add to the prior observations. Consequently, after a brief site visit to assess the potential value of further observations, the visit was abandoned. No report was filed as there was no field work done.

Appendix D – Soils Reports

Appendix E – Viscoelastic Aspects of Bench Design