Historical Overview of the RCP Industry

Introduction
It would be difficult to fully understand, appreciate, and explain our products to others without understanding how our industry and our product have continued to develop and improve over the centuries. RCP’s rich history and continued use is unsurpassed and cannot be matched by any other commonly used storm drain piping product available today. Our history makes us unique in the storm piping business and gives us a perspective that no one else has. The lessons learned and improvements made during the past are continuing to help us improve our industry and our products as we move through the 21st century.

The Early Days
Man’s desire and need to provide a healthy environment, transport goods, and improve agricultural development in the early to mid 1800’s created a demand for a way to properly move sewerage and accommodate storm water run-off. Concrete pipe used for agricultural drain tile and engineered sewer systems can be traced back to the early 19th century. The oldest recorded concrete pipe sanitary sewer installation was in 1842 in Mohawk, New York. There are also several installations of concrete pipelines that were installed in the late 1800’s that are still in service today. These installations prove that our product can provide a reasonable service life of 100 years or more. The concrete pipe industry does not need thousands of pages of research to develop a mathematical equation to CLAIM a particular service life; our product has a proven history of its strength, durability and service life.
Technology and Markets...1880-1930
From the late 1800’s into the early part of the 20th century the growth of the concrete pipe industry was influenced by related technical and market developments. Engineers began to understand how to predict and quantify storm water runoff amounts and develop methods to size pipelines. Also, during the first three decades of the 20th century, researchers at Iowa State University addressed many key components of pipeline design. They developed methods for estimating loads on buried pipe determined a methodology to calculate the supporting strength of rigid pipe culverts. As understanding grew, a desire for improved consistency and quality was desired by all stakeholders. The American Society for Testing and Materials (ASTM) became a forum for improved quality and movement of research and study into the market place. In 1904, ASTM Committee C-4 on Clay and Cement-Concrete Sewer Pipe was established. The C-4 Committee was made up of manufacturers and users of both clay and concrete sewer pipe and was the forerunner of the current C-13 Committee on Concrete Pipe. C-13 Committee scope includes RCP specifications, testing procedures, and definitions. C-13 still maintains jurisdiction over many of the most prominent production and testing specifications used for Reinforced Concrete Pipe. *(A full discussion of the various types of national specifications and standards bodies will be discussed later in a separate section of Training Module I)*

During the early and mid 20th century, as our countries major cities continued to develop and expand their service areas, the demand for sanitary and storm sewers grew at a rapid pace. During this same period, drainage for agricultural purposes was also experiencing rapid expansion. As the demand for drainage and sanitary sewer pipe grew, better production methods and equipment for pipe manufacturing was developed and introduced.

A rising need for comprehensive connected roadway system became evident in the early 1900’s as the number of automobiles grew from 50,000 in 1905 to more than 6 million in 1918. Our country and local governments had to organize, construct, and expand our public highway systems. As the demand for surfaced roads grew, so did the demand for RCP to meet the road systems drainage needs. By 1930 all states were using concrete pipe in their roadway construction projects.

Expanded Demand leads to Industry Expansion and Organization
The 20th century brought new technology, new standards, and a new rate of growth for the concrete pipe industry. The need to improve quality and production capabilities was recognized by our industry leaders. On Jan. 23, 1907, the Interstate Cement Tile Manufacturers Association was formed. In 1914, the name of the organization was changed to the American Concrete Pipe Association (ACPA)! The early pioneers in our industry clearly recognized, even in our infancy, that accurate product standards and uniform product quality were of the utmost importance.

The most significant development in our product in this early period was the introduction of the use of reinforcement in the concrete pipe wall. After 1916, almost all concrete pipe over 24” in diameter was manufactured with reinforcement.

The production of concrete pipe became automated and productivity rates were growing rapidly to meet demand. Tamp machines and the packer head processes were both developed in the early 1900’s. Production grew from one million tons to two million tons from 1925 to 1930.

Advancement of the Industry Post 1930
Following the great depression and World War II, annual production doubled to 4 million tons by 1950. By the early 1970’s more than 10 million tons were being produced, and by the middle of the 1970’s the annual market value of production exceeded one billion dollars. The
advancement of the concrete pipe industry from the 1930’s to the 1970’s can be attributed to the following major factors:

- Performance surveys verified the durability of RCP
- Increased acceptance of concrete pipe by planners, engineers, and government agencies
- Continued advancement in research and technology led to better understanding of our products and development of improvements
- Improvements of pipe production tools and finished product quality

1980-Present Consolidation, Competition, and Continued Improvements
The face (or at least the company names) of the concrete pipe industry changed due to consolidation in the industry, as large companies purchased many of the one and two plant independent operators throughout the 80’s and 90’s. Gone are the days when there was a RCP production facility in almost every other community along the highway.

Competitive products began an invasion of the sanitary and storm drain market, Polyvinyl Chloride PVC became the favorite choice for small diameter sanitary sewer in the late 70’s and in the 80’s, High Density Polyethylene (HDPE) pipe began its push into the storm drain market. By the late 70’s or early 80’s very little small diameter concrete pipe was been specified or used for sanitary sewer or agricultural drainage needs. By the mid 90’s HDPE had gained wide acceptance in the private development market and was beginning to make progress in the municipal and DOT market segments.

As competitive pressure grew, our producers once again focused their attention on improving product quality and production techniques. Many of today’s modern production facilities are fully automated & computer controlled. These new production facilities look and function more like an automotive assembly lines with robots and computers doing much of the work. New production methods, improved joints, and a constant drive to make a better quality finished product have helped us remain competitive and the best storm drain product still available today.

Summary of Historical Overview of Concrete Pipe Industry
Without RCP our nation’s cities would not function or be able to continue to support their residents with adequate sanitary sewers, storm sewers, and roadway culverts. Concrete pipe provides the backbone of our modern sewer and drainage systems currently in operation today over this country and the world. All of our nations’ most important transportation systems are supported by RCP. Our products history speaks for itself. RCP has proven to be strong, durable, and economically proficient to serve our countries needs and will continue to meet any demand identified in the future.

Required Reading and Study References
As referenced in the required reading materials, please read Chapter 1 of the Concrete Pipe Handbook to obtain a complete perspective on our industries and our products history and development. Without understanding the past, we cannot be prepared to look correctly into the future. In each study guide, we will recommend several references for you to read to properly prepare you for the test. The required reading will also help you obtain the background to understand subsequent topics. Knowledge can be gained by proper preparation and study. In the words of Abraham Lincoln, “A capacity, and taste, for reading (study) gives access to whatever has already been discovered by others. It is the key, or one of the keys, to the already solved problems. And not only so. It gives a relish, and facility, for successfully pursuing the unsolved ones.”
Materials & Manufacturing Process for Reinforced Concrete Pipe

Introduction
The quality of concrete pipe is a key factor that has contributed to its success and continued use. The quality is obtained from sophisticated facilities, processes, equipment, and knowledgeable people integrated under controlled conditions.

The concrete in precast pipe is of exceptionally high quality. All raw materials, coarse and fine aggregates, reinforcing steel, Portland cement, admixtures, and the mixing water routinely undergo quality control tests. Mix designs are developed to provide optimum strength and density, and actual proportioning is controlled by precision batching equipment.

There are several different processes used to produce high quality concrete pipe. New and improved machines and methods are continually being developed. In our study we will touch on the more commonly used production methods. We would suggest you review and develop an understanding of the particular production methods method or methods your firm uses to complete this educational experience. In the pages to follow, we will discuss briefly the component materials and the techniques and equipment used to produce a consistently high quality product.

Materials
Materials used to produce concrete pipe consist of locally available aggregates and manufactured products, such as Portland cement and steel reinforcement. Each of the products is covered by an ASTM standard relative to its properties and methods of testing.

Portland Cement, The “Glue” That Holds it All Together….The cementicious material (“glue” that hold all the ingredients together) in the concrete used to manufacture concrete pipe is composed principally of Portland cement. Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron, and small amounts of other compounds, to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Portland Cements are produced to meet ASTM Standard C 150 and classified into five types. This ASTM standard sets limits for chemical composition, fineness of grind, setting time, strength at certain ages, resistance to chemical attack, and rate of development of heat of hydration. Note: all types of cements are not available in every market area; find out from your production personnel what type of cement your operation uses and why.

Type I. Normal Portland Cement
Type I cement is a general purpose cement suitable for many uses. Type I cement can be used in any application not subject to sulfates or where heat of hydration is not critical. Sulfates found in soils, groundwater, or effluent can be highly aggressive to Portland cement concrete by combining chemically with certain constituents of concrete which leads to eventual disruption of the concrete. Sulfate attack caused by alkali soils primarily occur in the western and southwestern areas of the US. A detailed discussion of Sulfates is included in Chapter 6 of the Concrete Pipe Handbook.

Type II Modified Portland Cement
Type II cement has a lower heat of hydration than Type I, improved resistance to sulfate attack, and is intended for use in structures of considerable size to minimize temperature rise. Some
production facilities use Type II cement in the summer months to take advantage of the lower heat of hydration, and use Type I cement in the colder months due to its higher heat of hydration.

**Type III High-Early Strength Portland Cement**
Type III cement is used where high early strengths are desired. Production facilities might choose to use Type III cement when quick service/shipment of product is required, or during cold weather to protect against low temperatures.

**Type IV Low-Heat Portland Cement**
Type IV cement is used when the amount of rate of heat generated must be kept to a minimum, but strength development also proceeds at a slower rate. Type IV is rarely used in the production of RCP.

**Type V Sulfate Resistant Portland Cement**
Type V is a special cement intended for use in structures exposed to severe sulfate action. It has a slower rate of strength development than Type I. It provides better sulfate resistance than Type II cement.

**Blended Hydraulic Cements**
Blended hydraulic cements are blends of Portland cements and one or more natural or manufactured pozzolans. Pozzolans are materials that when placed in the presence of moisture; chemically react with calcium hydroxide to form compounds processing cementitious properties. Fly ash and blast furnace slag are commonly used pozzolans blended with Portland cement used for production of concrete to produce concrete pipe.

**Steel Reinforcement**
The amount of steel reinforcement is specified in ASTM C-76 or other ASTM standards. The type of reinforcement used depends on the production processes and local availability. The two most commonly utilized steel reinforcement types for RCP production are Welded Wire Fabric and Cold Drawn Wire.

Welded wire fabric is prefabricated from high-strength cold drawn wires and consists of longitudinal wires welded to transverse wires to form rectangular grids. Each wire intersection is electric resistance and welded by automatic welders. Smooth wires, deformed wires, or a combination of both may be used. Prior to 2009 wire fabric was manufactured to ASTM Standards A 185 or A 497.

Cold drawn wire is produced from hot rolled rods by one or more cold reduction processes that produce the size desired and improved surface, finish and dimensional accuracy. Prior to 2009 ASTM Standard A 82 and A 496 covered cold-drawn reinforcement used in the manufacture of pipe. The process of producing the wire cages for concrete pipe is usually manufactured by machines that are designed to produce a perfect diameter cage that provides proper required steel areas and strong welds at each wire intersection.

In 2009 ASTM Specifications for welded wire reinforcement and Steel wire were combined into one specification ASTM A 1064.

**Aggregates**
Aggregates are granular material of mineral composition, such as sand, gravel or crushed stone, and are combined with a cementing medium to form concrete. Aggregates for concrete pipe meet the requirements of ASTM C 33, except for gradation requirements. This specification sets forth requirements for grading, strength and soundness. Without sound, strong and properly shaped aggregates the finished concrete will not meet correct strength requirements. Aggregates are generally classified as fine or course aggregate.

Fine aggregate consists of materials ranging from a size passing a 3/8 inch down to material just passing the 100-seive (normal natural beach sand particle).

Coarse aggregate ranges from large sand particles to a size up to 1-inch.

**Water**
Water added to cement produces a chemical reaction termed hydration. Water reacts with cement to form a gel. The gel is formed by the penetration of water into the cement particles causing a softening and establishing a colloidal suspension. The taking up of water by the clusters of cement particles is the actual hydration. A small amount of water is required to hydrate all of the cement, however additional water is required to produce a workable mix. The water cement ratio is a critical component that affects the final strength of concrete. Generally speaking the higher the water cement ratio the weaker the final strength compressive strength of the concrete will be. Almost all of the concrete pipe mix utilized for the production of RCP has a very low water-cement ratio. The most typical manufacturing processes for RCP utilize relatively dry mixes. Most specifications require that the mixing water utilized for RCP be suitable for drinking.

**Manufacture of Precast Concrete Pipe**
The basic materials for concrete pipe are fine aggregate, coarse aggregate, Portland cement, steel reinforcement, and water. These are combined in a systematic manner, using quantities and proportions specially designed for each product. Fine and coarse aggregates are mixed with cement and water to provide a concrete mix which is formed into pipe by one of several methods. The newly formed pipe is properly cured and moved into a storage area until product is shipped to a construction site to be installed. The manufacturing process includes:

- Storage of materials
- Materials handling
- Reinforcement cage fabrication
- Batching and mixing of concrete
- Pipe Forming
- Curing
- Yarding and storage

**Storage of Materials**
Aggregates of various gradations are stored in bins. Portland cement and pozzolans are normally stored in above ground water tight silos, and steel reinforcement is normally stored near the cage fabrication area of the facility.

**Bulk Materials Handling**
Aggregates and cement are transferred from storage bins to weighing bins by loading equipment, or more commonly by conveyor systems. Weighing bins and or hoppers for cement and aggregates are normally electronically controlled. Once weighed, aggregates and cement are
combined with water in a mixer to properly mix the basic concrete materials. Once the concrete is batched and mixed, it is delivered to the pipe machine to form the pipe shape.

Reinforcement Fabrication
Cage machines and wire rollers are the most common methods utilized at this time to produce reinforcing cages in a concrete pipe plant. Cage Machines use reels of cold drawn steel wire and positions the longitudinal wires while wrapping the circumferential wire in a helix around the longitudinals. Intersections of the long wires and circumferential are automatically welded. The process produces a continuous cage. Wire Rollers use welded wire fabric in rolls or flat mats with desired size and spacing of longitudinal and circumferential wires. When the proper length of fabric has been formed by the roller, it is cut and properly welded to form the cage.

Cage Configurations
Two cage configurations are in common use: single circular cage and double circular cage. Additionally, single elliptical cage, combination of elliptical cage and one or more circular cages, and quadrant cage configurations may be utilized.

Steel Area
Steel area is a commonly used term for describing the reinforcement area in concrete pipe. When the term is used, it refers to the square inches of circumferential steel per linear foot; that is, if a section of pipe were cut length wise, the steel area is the sum of the cross-sectional areas of the exposed circumferential wires found in one linear foot of pipe.

Batching
Batching is preceded by design of the mix which provides the proportion of cement, fine aggregate, coarse aggregates, water and any admixtures used. Drum mixers and pan mixers are the two most common types of mixers used in the concrete pipe industry.

Slump Test
The slump test is the most common means of measuring the relative water content of cast-in-place concrete mixes. This common test method cannot be effectively applied to the mixes used for the manufacture of concrete pipe, because the slump of these mixes have such a low cement to water ratio they have a zero slump.

Pipe Production Methods
There are several methods for producing concrete pipe; they all use mechanical means to place and compact the concrete mix into the form. The dry-zero slump mix is placed in some type of form and the form is almost immediately removed and another pipe is produced using the same form set. One exception to the above method would be wet cast pipe. In wet cast production an inner and outer form is required and a higher slump wet mix is placed in the form and the forms cannot be removed until the wet mix concrete reaches an initial set and is safe to handle. There are many types and manufacturers of pipe production machinery that utilize the zero slump concrete. Most US manufacturers use a packer head method or some form of dry cast methods.

Dry Cast Method of Pipe Production
The dry cast process has several variations but all use low frequency- high amplitude vibration to distribute and compact the dry mix in the form. The form is removed immediately as the newly formed pipe can support itself.
**Packerhead Process**
The packer head process uses a device rotating at a high rate of speed that forms the interior surface of the pipe. It is drawn up through the exterior form as mix is introduced from above. The head has rollers or deflectors mounted on the top which compact the mix. When compaction is complete, the form and pipe is moved to a curing area where the exterior form is immediately removed and the form is transported back to the production station.

**Offbearing and Curing**
Removal of the pipe from the machine is called offbearing and can be accomplished in a variety of ways. The task of offbearing can be automated or manual and can be accomplished by overhead cranes, fork lifts, or other transport methods. The freshly made pipe is moved into a curing kiln by the offbearing equipment or by a moving floor system. Wet Cast pipe is cured while in the form and packerhead and dry cast pipe cure after the form is removed.

Curing starts immediately after the pipe is formed. Curing is optimized by control of kiln conditions and thus, the rate of hydration of the cement. There are three basic methods for curing: steam, water, and sealing membranes. The use of low pressure steam is the most common curing method in the concrete pipe industry. The principle of low pressure steam curing is that an accelerated rate of hydration produces concrete pipe of required strength in a shorter period of time than is possible when curing at ambient temperatures.

The three essential factors in all known methods of properly curing concrete are time, temperature and moisture. For equivalent strengths, an increase in temperature usually permits a shorter curing period. Concrete pipe can be cured in the open air, provided temperatures are high and constant. It is necessary under these conditions to maintain the pipe in a moist condition. A sprinkler system is most commonly used to provide such an environment.

**Yarding and Storage**
At the completion of the curing cycle the pipe is moved to the storage area. Before the pipe is moved into storage, a final visual inspection is completed and any minor imperfections are repaired. Marking of the pipe indicating strength class, manufacturing date, manufacturer, and other information as required by ASTM standards or local governing agencies is completed as the pipe is yarded.

**Summary of Materials and Manufacturing**
Quality products can only be accomplished by using good materials, the best production processes and equipment, knowledgeable and well trained personnel, good standards and quality control procedures. Our industry and our suppliers and equipment manufactures continue to work together to ensure the concrete pipe manufactured today is of the highest quality. The future success of our industry relies on our commitment to continue to improve our products and production processes. Please talk to your production staff and determine what materials your facilities use, verify your production process and type of machinery used. The best training exercise might very well be a thorough tour of one of your company’s production facilities.