Combining Hazardous Location Practices and Technologies in a Large Capital Project

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Abstract - The paper describes how North American and European installation methods and equipment were blended on a large capital project to achieve enhanced safety while at the same time achieving significant capital and installation cost reductions. The IEC Zone area classification system was used. The existing Canadian Electrical Code (CEC®) permitted the use of equipment certified to either Zone or Division hazardous location standards. Working with the local regulatory authority, traditional mindsets were challenged to enable the use of practices proven in various installation codes, with the fundamental principle of achieving equal or better safety compared to the existing code. The major areas that will be discussed are:

- Re-certifying or adapting Division type equipment to IEC standards
- Re-certifying or adapting IEC Equipment to CEC® requirements
- Obtaining approval for products not certified to Canadian Standards
- Using European installation concepts for North American certified cables
- Challenging specific Canadian Electrical Code rules
- Costs savings over traditional approaches are quantified where possible

I. INTRODUCTION

International trade demands local industries become more competitive to survive in the global economy. In addition, technology is changing at an exponential rate providing product solutions that often lead to more innovative and cost effective system designs. These economic pressures have caused industry to re-evaluate every aspect of how they operate in order to become more efficient. This includes reviewing and improving on how electrical installations are designed, constructed, operated and maintained while at the same time, maintaining an equivalent, or enhanced, level of safety.

A myriad of organizations around the world develop electrical installation codes, or recommended practices, and product standards. Despite differences in their content, albeit regional, national or international, the underlying objective of all of these organizations is to ensure electrical safety and to protect property.

Economic unions, such as NAFTA or the EU, have forced harmonization of codes and standards to simplify trade between member nations. In some cases the process may not be complete or may include national deviations. Despite this move towards harmonization, significant philosophical differences remain between countries or economic partners on what constitutes safe electrical installations and acceptable products. While some of these differences are technically motivated, many are essentially non-tariff trade barriers.

Understanding that no single jurisdiction or standards organization has the best set of rules in the world for all electrical installations, the challenge to the project was to use engineering capabilities and creativity to blend multiple standards to optimize safety and maximize cost benefits. This included elements from:

- National Electrical Code (NEC®)
- Canadian Electrical Code (CEC®)
- Canadian Standards Association (CSA)
- Underwriters Laboratories Inc (UL)
- International Electrotechnical Commission (IEC)
- CENELEC Member Countries and Certification Bodies
- IEEE

This paper examines the experience on a major project where the local Authority Having Jurisdiction (AHJ) permitted deviations from the electrical codes and product standards traditionally adopted by the Provincial Regulator.

While providing a number of unique solutions, the influx of new product technology presented a number of challenges to the design team and installers. Some new product designs were simply an adaptation of conventional equipment, and others were developed specifically for the project.

Electrical product selection was more closely linked to the project needs. While many traditional products were used, new products were developed to solve specific applications, CSA approved products were adapted to IEC standards and IEC products were adapted to CSA standards. A number of training sessions were held to keep the engineering consortium informed on these developments.

Although allowing multiple designers the ability to influence new product development led to a number of excellent concepts, it also led to a number of conflicting requirements. For example, the team working on the development of a Class I, Division 2 panelboard received daily changes from the engineering consortium. While many of the ideas were incorporated into the final design, others presented serious technological barriers or had major cost implications. The final version offered a number of benefits over traditional product offerings however with the increased amount of input in the development process, some delay in the availability of the final product was experienced.

Existing CSA approved products, such as lighting fixtures, were re-submitted for certification to IEC standards. Although this was a time consuming process, it was not overly difficult. The manufacturer assisted in a number of lighting designs with a consolidated fixture selection to simplify future maintenance. IEC equipment which provided solutions not found in standard North American products were CSA certified where possible and made available to designers. This included control devices and lighting products.

Training on the availability, application, installation requirements and conditions of use was provided to the engineering firms. The Engineering, Procurement and Construction contractors (EPCs) were expected to communicate any issues and new installation methods to the field. While this procedure may be fairly common, when dealing with the process was found to be somewhat ineffective. A critical factor in the installation requirements of one product type was not effectively communicated to the installers. Despite providing detailed instructions on the product, a number of installations required re-work.

The use of privatized Safety Codes Officers instead of the traditional provincial electrical inspectors was a major asset. Safety Codes Officers were included in design meetings, training sessions and briefed on all new concepts and changes to standard wiring methods.

II. PROJECT DESCRIPTION

The Athabasca Oil Sands Project is comprised of four specific elements: The Mine and Extraction plant, Pipeline, Upgrader, and Refinery Modifications. The Mine/extraction plant is located in the Athabasca Oil Sands about 70 kilometres north of Fort McMurray, Alberta. This is a large oil sands resource with high quality, well-defined mineable areas. Together with other leases located in the same area, there is approximately 1.5 billion m3 (over nine billion barrels) of bitumen recoverable through surface mining. This facility will include mine, extraction and froth treatment processes to produce approximately 1420 m3 (214,300 bbl/d) of diluted Athabasca bitumen, or 994 m3 (150,000 bbl/d) equivalent of undiluted bitumen.

One Pipeline transports the diluted bitumen from the Mine/extraction plant about 470 Km to the Upgrader site and a second line returns the recovered and make-up diluent to the Mine site. The Pipeline scope of work also includes additional pipeline facilities installed between the Refinery and the Edmonton shipping terminals for feed supply, product delivery and diluted bitumen bypass.

The Upgrader is located adjacent to an existing refinery located near Fort Saskatchewan, Alberta. The Upgrader processes the diluted Athabasca bitumen to produce Refinery feed stocks and custom blends for shipment via the Edmonton area pipeline terminals to other North American refineries, including other company refineries. The Upgrader will process additional feedstocks to complement the operation and product portfolio. The proportion will depend on market and seasonal factors. The Upgrader recovers the required quality diluent for recycle to the Mine and Extraction plant.

It was the company's objective to safely execute the project such that a minimum of 80% of the Upgrader nameplate capacity would be achieved by April 2003.

The Upgrader is fed from the Electrical Utility main substation via two 138 kV overhead lines, one directly to the Upgrader substation and the other via a separate co-generation facility substation on this site.

The Pipeline facilities and Upgrader blending facilities are fed from the Utility substation.

The Upgrader 138 kV substation contains two 138 - 34.5 kV transformers. The main plant switchgear is secondary selective with "A" and "B" buses at 34.5 kV. Sub-distribution voltages are 4160 V, 600 V and 120/208 V. A co-generation facility owned by an independent power producer, consisting of a 90 MW gas turbine generator (GTG) and a 90 MW steam turbine generator (STG) are connected to the main 34.5 kV switchgear via a 13.8 to 34.5 kV transformer. The 138 kV substation, the main plant switchgear, and the GTG and STG generators are located in the same area. Surplus power from the co-generation unit that exceeds the demand of the Upgrader is exported to the power grid.

The Mine and Extraction plant is powered by a main 260 kV substation fed by a transmission line connection to the Alberta Grid and a 180 MW co-generation facility. Distribution to the local plant substations is at 25 kV, including overhead 25 kV feeders to service remote site facilities such as the Mine and first pump station for the Pipeline. Variable Frequency Drives are used for all variable flow process applications, particularly slurry pumps. The main plant 25 kV system is a dual radial (A & B) bus design, capable of supplying the mine's electrical needs from either bus.

The on-site co-generation facility is owned by an independent power producer, and consists of two 90 MW GTGs. All process steam and electrical power requirements are provided from this plant. Sized primarily to meet the process plant heat requirements, the cogeneration plant produces excess electric power, which is marketed as merchant power into the Alberta electrical grid. The process plant is normally self-sufficient in meeting its electrical power needs, with backup electrical power available from the Alberta grid. Auxiliary steam boilers are also provided to ensure plant heat demands will always be met.

Table 1 Estimated Power Requirements

Facility	Power (MW)
Upgrader(34.5 kV)	**115**
Pumping Stations(25 kV)	
• Product Pipeline Pump Station	3.5
• Diluent Pipeline Pump Station	3.0
• Intermediate Pumping Stations	10.5
Subtotal	**17**
Refinery Modifications (25 kV)	
• Process Units	7.0
• Tank Farm	3.0
Subtotal	10.0
Mine and Extraction Plant (25 kV)	
• Plant	100
• Mine	10
Subtotal	**110**
Total Project:	**252 MW**

III. REGULATORY ENVIRONMENT

Electrical Codes

The Canadian Electrical Code system consists of two parts:

1. Part I – Safety Standard for Electrical Installations, which is often referred to as the Canadian Electrical Code (CEC®), and
2. Part II, Safety Standards for Electrical Installations. These are the Product Standards to which electrical equipment may be certified by the Canadian Standards Association (CSA) or other accredited certifying agencies.

The CEC® (Part I) is produced by CSA, and is adopted into law by all the individual Provinces and Territories, with or without deviations. It then becomes the required code for electrical installations in each jurisdiction. The CEC® requires that all electrical products used shall be certified to the Part II Safety Standards, which are also produced by CSA.

In addition to the CEC®, there are two other codes that are applicable to electrical installations in Alberta:

1. Code for Electrical Installations at Oil and Gas Facilities. This provides further interpretation and requirements to the CEC® with respect to hazardous locations for petroleum facilities, excluding refineries and petrochemical plants.
2. Electrical and Communication Utility Code. This applies only to public utilities.

Safety Codes System

Up to the mid 1990's, the Province of Alberta adopted the CEC® (Part I) and the additional codes, and provided Provincial inspectors to inspect all installations to ensure they met the requirements of the CEC®. Any deviations to CEC® rules or use of products certified to standards other than CSA Part II had to be requested from the provincial inspection authority. Requests for deviations were frequently refused on the basis of undefined "safety concerns", and there was no appeal process available. The uncertainty of receiving approval for deviations generally discouraged designers from pursuing them.

In June 1991, the Alberta Government passed the Safety Codes Act, which combined a number of pieces of legislation, one of which was the Electrical Act. A Safety Codes Council was set up to administer the new Act and to be an advisory body to the Provincial Government. There were nine major safety codes disciplines, these being plumbing, gas, electrical, boilers & pressure vessels, ski lifts, elevators, fire, and buildings. Under the main Council, a Technical Council was set up for each discipline. The Technical Councils have members representing various stakeholders with interests in those disciplines, such as government, industry, labour, institutions, municipalities, inspectors, CSA and utilities. Implementation of this new Safety Codes System went into full effect in early 1996.

Under the Act, Corporations were allowed to become accredited for one or more technical disciplines, where they then administered the provisions of the Safety Codes Act in those disciplines. In Electrical, the ongoing requirement for non-utility corporations was essentially to demonstrate to the Safety Codes Council that the requirements of the CEC® were being met.

Each Accredited Corporation was required to provide to the Safety Codes Council a "Quality Management Plan" (QMP) for their approval. The QMP outlined to the Council the manner in which the Corporation would demonstrate compliance to the requirements in the CEC®. QMPs were required the address the following key elements:

- Management commitment,
- Responsibilities and Accountabilities,
- Training,
- Inspection Requirements,
- Documentation, and
- Audits

The safety codes system also made provision for Corporations to obtain approval for deviations to the CEC® (now referred to as variances) from a Safety Codes Officer (SCO) if the deviation could be demonstrated to provide "equivalent" safety to the applicable CEC® rule. This included deviations to accept products that were not approved to CSA Part II standards.

The Safety Codes Act also made provision for the certification of SCOs and the accreditation of Agencies. Certified SCOs provide the inspection services previously provided by Provincial Government inspectors. Corporations have the choice of directly employing SCOs or contracting with accredited Agencies for the services of SCOs. Corporations directly employing SCOs must ensure there is an "arms length relationship" between an SCO and the work the SCO is inspecting.

Municipalities were also allowed to be accredited, and the requirements and responsibilities are similar to those of corporations. One major difference is that their jurisdiction was restricted to being within their municipal boundaries.

While the new Safety Codes System has basically performed well, issues do arise. Some of the major ones are:

- Acceptance of the new system by Municipalities. This has largely been resolved.
- Jurisdiction disputes between corporations and Municipalities. To a large extent, much of this issue is related to corporate changes, such as new corporations coming into the Province or selling assets to other companies. In some disciplines, this is still an issue.
- Jurisdiction disputes between the Municipality where skids or modules are manufactured and the Authority at the location where the skid or module is to be installed.

In the electrical discipline, implementation of the new Safety Codes system has been successful, and numerous corporations have become accredited. The accredited corporation may employ or contract the services of SCOs who are familiar with industrial installations. Therefore, when a "variance" is requested, the SCO is more likely to understand the technical and safety implications, and as a result can better judge that the variances would provide "equivalent safety". The responsibility is on the corporation to demonstrate "equivalent safety" to the SCO.

Project

The operating company applied for and received corporate accreditation in the electrical discipline for all facilities under its care and control.

This accreditation applies to all its existing facilities, plus all the new facilities for this project. The pipeline portion of the project is not included, as it is owned and operated by another party. The mine area itself is also not included as it falls under the jurisdiction of a different Government department and is subject to a separate code. However the extraction facilities at the mine site were included in the accreditation. The co-generation plant at the mine site was built by a 3rd party and fell under the corporate accreditation of that 3rd party, however since it is operated as an integrated extraction/co-generation facility, the ongoing electrical accreditation was passed to the operating company.

A "variance policy" was included in the company's QMP, which outlined the process used to take a variance at any of it's facilities. This enabled the project to take full advantage in implementing deviations to code rules or equipment standards that is allowed under the safety codes system.

IV. ENGINEERING AND DESIGN

Area Classification

The CEC® Zone classification system was used for this project. This system is similar to the NEC® Article 505 which are both based on the IEC. Using currently accepted area classification practices, in excess of 97% of the hazardous locations were designated as Zone 2. The balance was Zone 1 and an extremely small percentage of Zone 0 locations.

Cost Savings in Design

Unlike "recommended practices" used elsewhere, both the CEC® and NEC® contain prescriptive rules which provide specific details on how installations are to be completed. Since these codes deal with residential, commercial and industrial installations in a single document, many safety objectives intended to protect the general public are often incorrectly imposed upon large industry.

While prescriptive requirements of the CEC® might appear to simplify design, they often conflict with innovative design practices. Frequently, requirements are so prescriptive that there is no need for design. However, there are often alternatives that may be more cost effective and which do not compromising safety. In these cases, engineers and designers were encouraged to use their knowledge and experience towards achieving more innovative and cost effective approaches. In doing so, they research global practices that could be applied to their specific situation. If the new design is not accommodated by mandatory prescriptive code requirements, variances to the existing rules are written to use the new design. The variance process was used to document cost effective, innovative engineering solutions. These variances were developed by the design engineers, approved by the safety codes officers and stored as part of the permanent record of the design decisions made on projects for future reference.

Variances

Numerous Variances to the Canadian Electrical Code (CEC®) were used throughout the project where it could be demonstrated that a significant advantage could be gained by the project without eroding safety or reliability. The following are a number of the key variances to the CEC®®used on this project:

1. Random Fill of Cable Trays:

The CEC® requires significant de-rating of cables if cable spacing in trays is not maintained.

This variance allowed branch circuit cable trays to be random filled without the need for de-rating where maintained cable spacing was not practiced. Maintained cable spacing would require much more cable tray to be installed and more labour in installing cable. De-rating of cables would cause a significant increase in the cable costs. Because of the diversity provided by spare cables and cables not operating at their rated ampacity, it is acceptable to not de-rate branch circuit cables. The estimated savings to the project were in the order of 57% of the applicable cable costs.

2. Non-Approved Equipment:

The CEC® requires that all installed electrical equipment be approved. The CEC® defines "approved equipment" as being certified to CSA Part II Standards by a certification organization accredited by the Standards Council of Canada.

Numerous variances allowing the use of equipment approved to standards other than CSA Part II were used. This equipment was approved to other nationally recognized standards and the variance simply identified the similarity of the application in this jurisdiction. This saved significant cost and eliminated the schedule delays associated with replacing "non CSA approved equipment" or recertification of equipment already certified by other qualified Certification Bodies by CSA. Since recertification requirements vary significantly between types of equipment, the actual cost savings achieved was difficult to quantify.

3. Minimum Voltage Drop:

The CEC® requires that branch circuits have a maximum of 3% voltage drop. This often required that cables be oversized to meet the voltage drop requirement, resulting in a voltage at the end device exceeding its rating. For example, on 600-volt systems, a 3% voltage drop limit required an increase in conductor size when the voltage at motors was lower than 582 volts. However, the rating of motors is 575 volts.

This variance allowed deviation to the basic voltage drop rules. The criteria for accepting higher voltage drops were that the voltage at the end device would fall within the specifications of the end device. This allowed the voltage drop in the overall distribution system to be managed verses following the restrictive rules on voltage drop in individual branch circuits. Where deemed acceptable, voltage drops in excess of five percent were used, for instance, the voltage drop allowed to some remote heat tracing circuits was as much as eight percent. This variance resulted in reduced cable size, particularly for motor feeders and electric heat tracing circuits. Total savings of 17% of the applicable cable cost was realized by this variance.

4. Non-Approved Cables:

The CEC® accepts CSA certified Tray and armoured cables in Zone 2 locations, and armoured cables in Zone 1 locations.

This variance allowed cables approved to other standards that are deemed safe for the particular application to be used. Cable costs are a major element of the overall electrical cost of an industrial installation. It was determined that significant cable cost reductions could be achieved by allowing more competition and permitting other acceptable cable types. In addition to CSA cables, UL certified cables were accepted, and sourcing of cables for this project was based on cables approved to CSA or UL standards.

5. Tray Cable Protection by Location:

The CEC® requires that Tray Cables be protected by approved raceway.

This variance reflected the fact that Tray Cable can be protected by its location and did not need to have additional protection (conduit sleeve, etc.) where it is outside of the cable tray in those locations. Savings of 16% for the applicable cables were realized.

The NEC® does recognize protection by location but the rules are not necessarily clear.

6. IEEE Ampacities:

The CEC® requires that maximum conductor ampacities shall not exceed the values listed in the CEC® tables. The CEC® ampacities are "worst case" and as such are overly conservative for many situations. The ampacity values in the NEC® are much closer to those in the IEEE.

This variance allowed the recognition of IEEE ampacities for power cables. Numerous instances of conductor size reductions were encountered in large power cables. Significant costs were saved on main feeders, where savings were estimated to be in the order of 14%.

7. Maximum Temperature for Heat Tracing:

The CEC® requires that the sheath temperature must be below the auto-ignition temperature in hazardous locations.

This variance recognizes that the heat tracing of hot piping will be allowed to operate at a temperature up to the normal operating temperature of the pipe in Class I Zone 2 areas. Often, this pipe temperature is in excess of the listed auto ignition temperature of the gases. This significantly reduced the need for multiple parallel runs of heat trace cable on pipes located in hazardous locations and are traced for freeze protection. American Petroleum Industry Publication 2216, “Ignition Risk of Hydrocarbon Vapours by Hot Surfaced in the Open Air” suggests the ignition temperature from hot surfaces in open air may be as much as 200 ^{O}C above the laboratory determined values in published tables. Savings of up to 50% were realized for tracing circuits where rule changes were applied.

8. Bonding to Ground of Instruments in Hazardous Locations:

The Both the CEC® and NEC® require that all non current carrying parts of electrical equipment shall be effectively bonded to ground.

This variance recognized that instruments were effectively bonded to ground in hazardous locations by their connection to the process piping and structural steel they were connected to. Therefore the requirement for a bonding conductor in the instrumentation cable was not required. This reduced the cable cost and reduced termination costs.

9. Motor Feeder Sizing Reduced to 115% FLA

The Both the CEC® and NEC® that motor feeders be sized to 125% FLA.

This variance recognized that motor feeders for medium voltage motors could be reduced to 115% FLA because the electronic overload units can be set to accurately protect the motor feeder cables at this level. In most cases, this can reduce the cable sizing requirements. It was recognized late in the project that this was possible, but it was too late to implement.

V. PRODUCTS AND EQUIPMENT

The selection of equipment that was to be applied to this project was based upon using the 1998 Canadian Electric Code but not limited to it. The following are some of the key areas where new products were used, developed, or variances to accept non CSA approved equipment were made:

1. Restrictive Breathing Fixtures Ex nR:

The lighting design for Zone 2 locations was based on using restricted breathing technology, Ex nR. In many areas of the project, the published ignition temperature was as low as 230 ^{O}C. Since restricted breathing fixtures use external temperatures rather than internal temperatures as a basis for determining their T-Code, much higher wattage Ex nR fixtures could be used in low AIT (auto-ignition temperature) areas. As a result, a significant reduction in the total number of fixtures was achieved and the use of more expensive Class 1, Div. 1 (Ex d) fixtures was avoided. Savings of approximately 47% of fixture costs were realized by using Ex nR fixtures where lower wattage or Ex d fixtures would have otherwise been required.

Similarly, floodlights that incorporate restrictive breathing technology were used, allowing for lighter weight floodlights with better optics that enhanced light distribution over traditional Div. 2 floodlighting.

Table 2 illustrates the lower temperature codes for “Ex nR” fixtures verses Div. 2 fixtures.

Table 2 Light Fixture Temperature Codes

Wattage (HPS)	Div. 2 T-Code	Zone 2 "Ex nR" T-Code	Change in Temperature Rating
70	T-3	T-4A	+120 ^{O} C
100	T-3	T-4A	+120 ^{O} C
150	T-2B	T-3C	+100 ^{O} C
250	T-2A	T-3C	+80 ^{O} C
400	T-2A	T-3C	+80 ^{O} C

2. IEC Type Control Stations:

The use of IEC type control stations facilitated the application of tray cable and eliminated seals, either field or factory poured. The IEC type control stations chosen were housed in a non-metallic IP66 enclosure, which reduces corrosion and maintenance problems in the future. Gold plated contacts were used throughout the project. These were chosen because areas where there were low current signals, analog or digital, minimizing problems with contact corrosion. For uniformity, gold plated contacts were also used on power circuits as there was no difference to the performance and the cost was the same.

3. IEC Type Welding Receptacles:

The decision to use IEC type welding receptacles was based on the fact that the over all installed cost vs. the Division style was less, with the equipment being lighter in weight, smaller in overall design, the elimination of seals and less man hours to install. There is also a long-term reduction in maintenance by using an enclosure that is easier to work on and is less likely to sustain damage under normal maintenance practices.

4. Tray Cable Connectors:

With the use of tray cable, a proper connector was needed. A close examination of the IEC type tray cable connector show that although it had all the required ratings for Zone 2, it’s down fall was metric threads, small throat length and metric diameters which made it unsuitable for standard tradesmen tools. After examining non-hazardous location cable connectors, the choice was made to use a non-metallic connector with NPT threads, standard imperial diameter measurements and a longer throat. A variance was written to use these connectors, which were not specifically approved for hazardous locations.

Note: The CEC® has since been revised to remove the requirement to use connectors approved for hazardous Zone 2 locations much like the NEC®.

5. Fluorescent Egress Lighting:

IEC type Zone 2 fluorescent light fixtures were chosen for various applications including egress lighting, where this light source was selected due to energy efficiency. The IEC type fixture was fitted with North American ballast that were rated 120 VAC /125 VDC so they could run off of utility and UPS power. Also after comparing the IEC and Division type fixtures, it was found that the IEC type fixtures offered the following advantages: more rugged construction, more lens options, and they were more widely used throughout industry although not in North America.

6. Panel Boards:

The existing range of available Class I, Division/Zone 2, and CSA approved panelboards was limited.

Available Option 1: A cast aluminium enclosure with two chambers. While cables between the chambers were sealed, the main incoming feed still required field installed seals. All branch circuit cable entries needed to be drilled and tapped. This style of panelboard typically cost more than the other units considered and also had the highest installation and maintenance cost.

Available Option 2: A Cast enclosure with a small NEMA style box attached for field wiring connections. Again, while cables between the chambers were sealed, the main incoming feed still required field installed seals. The available field wiring chambers were the same throughout the offering. The limited space on 36 and 42 circuit panels made wiring difficult and time consuming.

Available Option 3: IEC Zone 1 panels. While the concept was acceptable, experience had shown these to be cost prohibitive.

An opportunity to be involved in the process of designing a new lighting and power distribution panel came from the manufacturer, which was able to take ideas from IEC type equipment and combine it with North American technology to evolve into a hybrid panel. An increased safety terminal chamber was combined with an explosion proof panel board, with all wiring in the terminal box and all cables sealed between the two chambers. The terminal box could be provided in many sizes and materials to suit the environment and simplify installation.

In the final stages of the project, a new generation of panelboard became available which eliminated the need for the explosion proof enclosure. This product required a variance due to a certification issue with CSA.

VI. INSTALLATION AND WIRING METHODS

Wiring, installation materials and associated labour represent up to 40% of the total electrical budget. Consequently, there are many areas where considerable cost savings are available. The project was able to achieve significant cost savings in this area by applying the following principals:

1. Cables:

Project standards were developed to allow UL cables to be specified that were essentially equivalent to the CSA Cable Standards. Detailed knowledge of both the CSA and UL Cable Standards was essential in developing these specifications. This approach could have been extended to include other Cable Standards (such as IEC), but due to the effort required, it was decided to limit the "equivalence" exercise to only UL Cables on this project. Traditional "TECK Cable" was replaced by UL or CSA "Tray Cable" for small power and instrumentation cable at 600V and below. Type ACWU cable replaced TECK for 600V applications above #1 AWG. Type ACWU cable is similar to TECK in that It has an interlocked armour with an overall PVC jacket, however, it differs in that it has no inner jacket under the armour and the conductors are aluminium. Non-armoured, FT-1 flame spread rated power cable was employed for the 35 KV feeders. ACWU was also accepted for medium voltage applications, but due to availability, it was not used.

The NEC® permits only conduit and HL-MC type armoured cable in Zone 1 locations. Both option involve much higher installation costs and were excluded early on in the project. In Zone 1 areas where armoured cables were used, TECK was a much better choice due to its flexibility and ease of installation. In Zone 2 areas where the additional protection of armour was required, ACWU cables were used for their cost advantage over TECK.

The material cost savings ranged from 10% for ACWU to 50%+ for Tray cable pairs and triads. The cables employed were lighter, smoother (tray cable) and/or smaller diameter than traditional cable types. Field labour savings were estimated to be in the range of 15%-50% depending on the type of cable used, compared to that of traditional cables.

2. Protection by Location:

European petroleum and petrochemical facilities have utilized "protection by location" principles for decades. These principles were employed in order to eliminate conduit sleeves, flexible conduit and other raceway materials where the cables were not subject to mechanical damage. Savings of approximately 16% for applicable cable installations were realized by using this installation approach.

The NEC® does recognize protection by location but the rules are not necessarily clear.

3. Tray bonding:

Tray bonding in corrosive petroleum/petro-chemical environments is typically achieved with green insulated copper conductor connected to the tray system by Cu/Al connectors. Bare aluminium bonding conductor was chosen, which eliminated the expensive connectors, glyptal treatment, and stripping insulation. Tray bonding costs were reduced by 16% using this approach.

4. Non-Metallic Enclosures:

FRP (fibre reinforced polyester) enclosures were widely used for corrosion resistance, and aluminium cable glands were replaced with non-metallic glands. This eliminated the need for bonding connectors when tray cables (without grounding conductors) were employed. Savings in material and labour costs ranged from 35% to 50% for the applicable enclosures.

5. Tray system installation:

The aluminium cable tray system was designed without employing cable drop hardware, end plates and associated fittings. Savings of 10% of the fitting costs were realized.

Many challenges were experienced in the implementation of these new and often "foreign" approaches. Monthly meetings were held with the design teams in order to discuss implementation issues, and develop design, installation and detail standards. The installation concepts were not well understood by some and not well received by others. The reduced installation labour component was seen as a negative by the construction forces ("takes away jobs"). Construction personnel familiar with armoured cable and conduit installations were uneasy with the use of tray cable in an industrial application. In retrospect, the project should have expended a greater effort on training the construction forces.

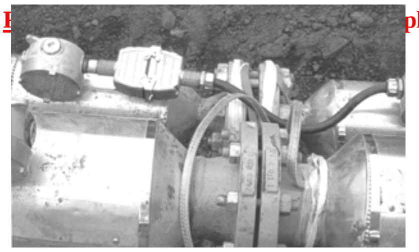
VII. Plug & Play Wiring

Introduction

Plug & Play wiring is simply using plugs rather than terminal blocks to terminate wiring to field devices. The drivers for switching to this technology are increased safety, capital and operating cost reduction.

Plug & Play Applications

Plug & Play (P&P) has been employed in lighting systems in Zone 2 locations to interconnect lighting luminaries. Instrumentation systems have utilized Plug & Play to connect logic processors to field marshalling cabinets in instrument rack rooms and for the connection of instruments in the field in Hazloc areas. Current practice is to modularize pipe racks and build the modules off-site in module yards. Piping is heat traced and insulated in the module yards. Heat trace segments must be reconnected across the piping flanges when the modules arrive in the plant. P&P has been used to interconnect MI heat tracing across pipe rack shipping splits.



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Plug & Play Lighting Application

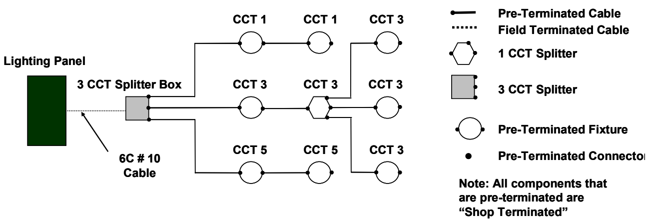


Figure 2 Plug & Play Lighting

Conventional multicore tray cables are used to run lighting circuits from the electrical panels to the lighting hazardous areas. The cables are terminated in 3-circuit splitter boxes, which are used to split the lighting into phases, A, B and C. Each phase has its corresponding plug connected to the splitter boxes.

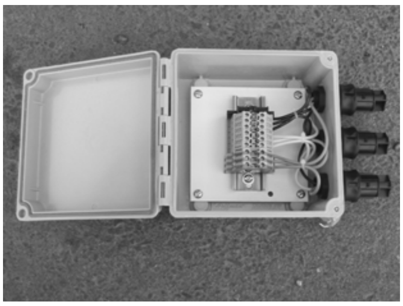
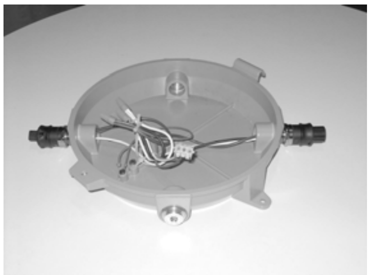


Figure 3 Splitter Box

Cord sets (EX nA II X approved male and female plugs suitable for 600 volts, 20 Amps, IP 66/68) were attached to the Tray Cable cord in a fabrication shop. The cable sets are fabricated with 5, 10, 15 and 20 meters length.

Lighting fixtures are wired with male and female plugs to enable pass-through wiring. Internal connectors were provided for disconnection of the ballast/lamp housing.

Figure 4 Fixture Housing



T- Connectors provided up to 3 branch connections from one incoming feed. Unused ports were plugged off

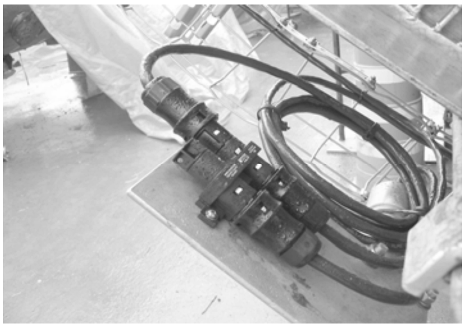


Figure 5 T-Connectors

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The plugs positively snap into the mating plug and require a tool to remove once connected. The cable sets were laid in cable tray, basket tray or channel between fixtures. Excess cable was neatly "lost" in the tray.

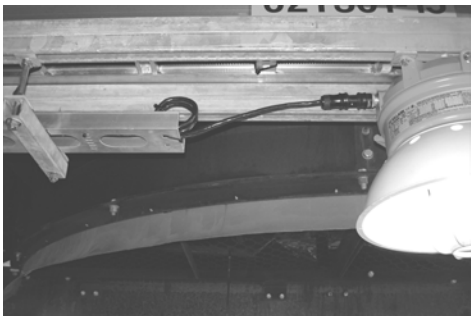

Figure 6 Excess Cable "lost" in Tray

Cost Comparison

Plug & Play wired lighting reduced the installed lighting cost by approximately 40%. Labour savings of 65% were realized by employing these wiring methods.

Plug-and-Play Cost Comparison		
• Field installation • conventional wiring • rigid conduit	Material Labour Total	$418.28 $1017.58 $1435.86

• Off site fabrication • rigid conduit • modular wiring	Material Labour Total	$464.88 $363.35 $828.23
• Off site fabrication • Swivel pole • modular wiring	Material Labour Total	$658.46 $438.75 $1097.21

Lighting Benefits

The following benefits are realized by employing P&P wiring:

Safety: Plug & Play eliminated the need for "hot work" maintenance. When exchange of ballast housing is done, the major work is done in a shop, rather than attempted repair in the field.

Construction: Labour savings of 65% are often realized on the installation. Wiring/testing of equipment was carried out in a controlled shop environment eliminating errors and reducing field checkout and start-up costs.

Maintenance: Plug & Play provides quicker turnaround time on equipment exchange. Ballast/igniter servicing can now be performed on an exchange basis in the shop rather than up the pole. These exchange services reduce rewiring errors and reduce lighting downtime.

Plugs and Play Conclusions

Modernizing wiring systems, cable types and installation techniques significantly reduces the costs of electrical installations while improving maintainability and safety. The engineers and designers working on projects employing modern wiring methods need to become familiar with many product standards, tests and options to ensure that all project requirements are satisfied

VIII. INSPECTION

Safety codes inspections were handled by a team of third party safety codes officers (SCOs) via an Agency accredited by the Province to provide this service. This team provided the following "value add" over traditional regulatory inspectors:

1. The SCOs worked proactively with the EPC engineering teams to ensure that code compliance was managed with minimal disruption to the design process.

2. Input was provided to the procurement process to ensure that the correct hazardous location equipment certification requirements were included.

3. Inspection of "vendor packages" was undertaken at the vendors' shops so that code/quality deficiencies could be corrected prior to package delivery to the job site.

4. The SCOs worked proactively with the engineering teams to develop Safety Code Variances to the CEC®, which were incorporated throughout the design and installation process, resulting in major cost savings.

5. The SCOs provided assistance in the field to interpret "protection by location", and assisted in obtaining approvals and/or variances for equipment that was delivered to site with the wrong certifications. This greatly reduced delays and reworking in the field.

6. The Agency developed and maintained the project's records for Safety Codes Variances and inspection records (as per audit requirements).

IX. TRAINING AND EDUCATION

Once the decision for the use of blended wiring methods was made, and appropriate products and equipment was selected, the next step was to ensure that all the engineering companies involved were aware of what was required for the project and that all parties including engineers, designers and field personnel understood the principles and their proper application.

A series of ongoing meetings though out the project were set up with the electrical leads from the engineering companies, owner and involved manufacturers to discuss the approach taken on wiring methods and equipment that were to be applied to this project, and determine what products were available to be used. The basic principle of not compromising safety was maintained.

The next step was to train the designers from the engineering firms. This was accomplished by having the electrical lead engineers take back information from the ongoing meetings with each other and the owner, and making sure everyone in their home offices was up to date with the understanding of how the project design was to be approached.

Where appropriate, manufacturers held training seminars with the engineering companies on specific products. For example;

- how hazardous location products in general could be adapted for use with tray cable,
- highlighting design opportunities with IEC equipment, and
- identifying equipment options from what was traditionally used in hazardous location applications to the optimize the blend of IEC, NEC®, and CEC® type equipment properly.

The intent of this training was to challenge traditional mindsets to achieve the overall design criteria and maximize cost savings, while at the same time ensuring safety was not compromised.

The next step was to ensure the field people, including inspectors and installers, were trained on how the equipment was to be installed and wired. The Safety Codes inspection Agency was included early in the education cycle and was involved in many of the meetings held throughout the design process.

The installers were familiar with some of the equipment but should have had better training in some areas. In the case of the "Ex nR" light fixtures, the requirement to have the cable entry sealed was not properly done, as the installers assumed that the installation of this fixture was the same as had been done in the past with Div. 2 fixtures. This resulted in a closer look at the area classification, and a determination if the fixtures did indeed require sealing to retain the "Ex nR" rating. Where it was determined the "Ex nR" rating was needed, the fixtures were removed so that they could be sealed correctly.

The over all approach of education and training to everyone in the process, led to a consistent and cost effective design and installation for the project.

X. MAINTENANCE CONSIDERATIONS

One specific reason for choosing certain types of equipment was based on reducing long-term maintenance costs. A close look at traditional North American hazardous location equipment pointed out several areas that have on going day-to-day maintenance costs in the field.

The project mandate was to select equipment that can potentially reduce ongoing operation and maintenance costs. Some examples of this requirement are:

1. Eliminate where possible the use of explosion proof enclosures. Long term, this will increase the accessibility and environmental integrity by not relying on numerous bolts required to be tightened to specific torque values as required by their design. This also eliminates the possibility of the flame paths being scratched or damaged accidentally and bolts being stripped, thereby improving safety performance and the need for costly repairs.
2. Dual arc tube lamps for all HPS light fixtures were used, which reduces the maintenance costs of replacing standard HPS lamps. A standard HPS lamp has a rated life of approximately 24,000 hours where the dual arc tube has a rated life of approximately 40,000 hours. This increase of 60% to the lamp life extends the period between re-lamping to the same percentage. Another consideration for using the dual arc tube lamp was the elimination of the need for the instant re-strike option for the fixture, which when used, many lamp manufacturers will not warranty the lamp due to the high electrical impulse the device creates. Instant re-strike is used to restart the lamp to minimize the amount of time that the light is "out" during a brown out or momentary power disruption.

3. The use of the cast division style panelboards with NEMA 4 wiring compartments for all field-wiring wiring points, including the mains, allowed easy access to the primary maintenance interface. This eliminates the need to access to the breaker enclosure except to replace or add the breakers themselves.

   Additional factory sealed wiring was provided for spares, which was sized to the maximum breaker size anticipated, connected to terminal blocks in the NEMA 4 enclosure and bundled in the cast enclosure for future use. Since the breaker housing is considered "factory wired", there is a reduction in the wiring space required by the standards. This allowed for a more compact cast enclosure to be used, which significantly reduced the number of bolts required.

   These advancements significantly reduce the maintenance costs associated with adding or changing circuits and servicing breakers.

XI. CONCLUSIONS

Technology is changing at a fast pace and as a result, the world is shrinking. In order to remain competitive in a global market, best practices from around the world need to be applied. This paper has demonstrated how considerable cost savings can be realized by appropriate selection and application of equipment certified to IEC/NEC®/CEC® standards and European/North American installation methods. Working with the local Regulatory Authority, traditional mindsets were challenged to enable the use of practices proven in various installation codes, with the fundamental principal of achieving equal or better safety compared to the requirements of the CEC®.

XI. REFERENCES

[1] API PSD 2216, Ignition Risk of Hot Surfaces in the Open Air

[2] Integrating Global Hazardous Location Methodologies and Technologies in a Large Capital Project – IEEE-PCIC 2003

[3] Evolution of Wiring Systems - IEEE PCIC Europe 2006

XI. VITA

Marty Cole has worked for Hubbell Canada for over 25 years and has been involved with hazardous locations for much of that time. He is a member of the Canadian Electrical Code (CEC®) Part I - Section 18 Subcommittee and CSA's Integrated Committee on Hazardous Location Products. He was vice-chair of the task force that added the IEC Zone System to Section 18 and chaired the committee that adopted the IEC 60079 Series standards as CSA standards.

Marty is chairman of the Hazardous Location Products sub-section of Electro Federation Canada's (EEMAC) Wiring Products Section, a member of the Advisory Committee for the Objective Based Industrial Electrical Code (OBIEC), along with a number of other CSA Part 2 and IEC standards and technical committees. He has authored and co-authored a number of papers and articles on the subject of hazardous locations for the IEEE-PCIC, IEEE-IAS Magazine, EX Magazine and other industry publications.

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