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Chips or cores –
what's best in
exploration?

Voisey's Bay –
newest jewel in Inco's crown

INCO

Inco's gem



Prospecting for diamonds led to the discovery of a great base metal deposit that **John Chadwick** says will be at the forefront of cutting edge hydrometallurgy

On November 16 last year, Inco achieved another major milestone at its Voisey's Bay project, some 35 km southwest of Nain in northern Labrador, Canada, with the first shipment of nickel concentrate. Managing Director of Voisey's Bay Nickel Company (VBNC), Phil du Toit, points out that: "Both the mine and concentrator and the demonstration plant were completed more than eight months ahead of the original project schedule, with an exemplary safety record." The concentrate was shipped to Quebec City – and from there was sent to Sudbury by rail. Inco expects to produce finished nickel from the Voisey's Bay concentrate in this first quarter of 2006. With nickel prices at all time highs, the timing was great and would help Inco start recouping some of its vast investment. It paid a lot to buy the project and is paying a lot to develop it.

Having reached an agreement with the Province of Newfoundland and Labrador, the LIA and the Innu Nation, Inco installed temporary infrastructure in 2002. In 2003 the construction effort focused on building civil infrastructure. Having that civil

infrastructure in place allowed Inco to finish the permanent facilities, start Mechanical Electrical Piping and Control (MEPIC) and begin prestripping in 2004. Production will ramp up over the coming months. 2005 saw the completion of MEPIC, the permanent infrastructure and the tailings dams. Mining began in April and the mill started up in September. The annual production capacity of the Voisey's Bay project is expected to be 110 Mlb of nickel in concentrate, containing 5 Mlb of cobalt and up to 15 Mlb of copper. The project will also produce copper concentrate containing approximately 70 Mlb of copper annually.

This has been a tremendous achievement as a greenfield development in a remote area with access to shipping. However, it has perhaps been an even greater achievement in stakeholder negotiation and involvement. Negotiations were long and difficult and had to accommodate overlapping and unsettled land claims from the Innu Nation and the Labrador Inuit Association (LIA). Project coverage in the media had raised high expectations among local inhabitants and politicians. These had to be rationalised

Loading of the first concentrate.

to achieve a realistic level. The multi-party environmental assessment involved the Canadian and Newfoundland Governments, the Innu Nation and the LIA.

Part of the stakeholder success has been in local procurement and employment. Of the contracts awarded, 81% went to Newfoundland/Labrador companies, with the majority going to Aboriginal companies. Aboriginal companies were awarded procurement/construction contracts worth in excess of C\$500 million. Residents of Newfoundland and Labrador accounted for 81% of all the people who worked on all aspects of the project. Now that it is operating, 98% of the mine and concentrator workforce are from Newfoundland and Labrador – of which 80% are residents of Labrador and 50% are members of either the LIA or the Innu Nation. At Argentina, 90% of the hydromet R&D team are residents of the province – 55% are from the Argentina area and 32% are women.

The discovery of Voisey's Bay is one of the great stories of geological lore. Prospectors

Al Chislett and Chris Verbiski were looking for diamonds when they spotted rusty outcrops in Northern Labrador in late 1993. When they chipped samples from an iron stained outcrop, they made one of the most substantial mineral discoveries in Canada in the last 40 years. It did not take long before they started to realise the magnitude of what they had discovered. Results came quickly. In November 1994,

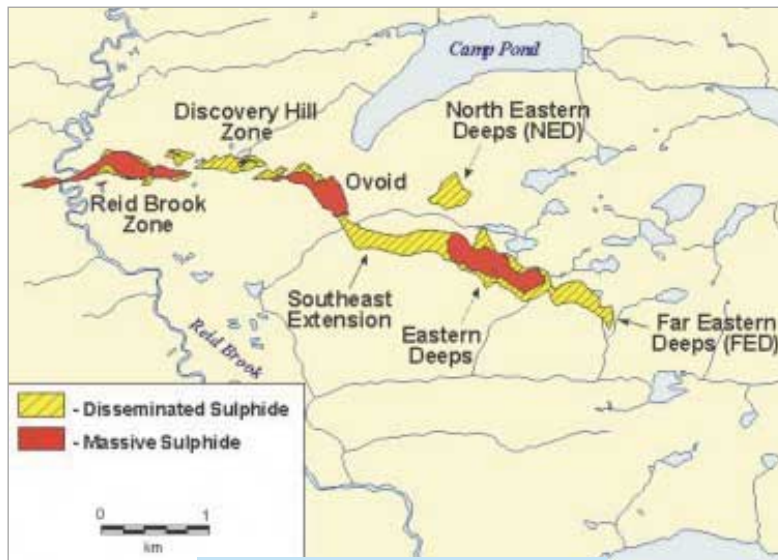
Diamond Fields, the company that funded Chislett and Verbiski, announced a major nickel-copper-cobalt sulphide orebody, and by July 1995, drilling had defined 31.7 Mt of ore at 2.83% Ni, 1.68% Cu and 0.12% Co.

Until this discovery, the igneous and metamorphic rocks of eastern Labrador were not generally considered to be promising areas for base metal prospecting. Indeed government geologists had known of these outcrops, but had dismissed them as unpromising. Exploration soon revealed a bowl-shaped orebody lying just below surface. This deposit, known as the 'Ovoid', has surface dimensions of some 800 m by 350 m, extends to depths of about 125 m and is being mined by an open pit. As of year-end 2004, the Ovoid contained estimated proven and probable reserves of 32 Mt grading 2.82% Ni, 1.54% Cu and 0.14% Co. In addition, there are an estimated 50 Mt of indicated mineral resource grading 1.64% Ni, 0.78% Cu and 0.1% Co and 12 Mt of inferred mineral resource grading 1.7% Ni, 0.7% Cu and 0.1% Co available as part of the Voisey's Bay project.

The ore is largely pyrrhotite (iron sulphide), containing 59% Fe and 34% S. The principle nickel sources in the ore are pentlandite (nickel-iron sulphide) and millerite (nickel sulphide).

Massive exploration

The mineral resources are contained within three deposits. The Eastern Deeps zone is part of but lies 1 km east of the Ovoid. Unlike the Ovoid, the Eastern Deeps mineralization begins about 500 m below the surface and extends to depths of 1,000 m. The Discovery Hill and Reid Brook deposits



- 32 Mt proven and probable reserves
- 50 Mt indicated mineral resource
- 12 Mt inferred mineral resource

occur 1 km and 2 km west of the Ovoid, respectively. So eventually Voisey's Bay may support both open pit and underground mines, operated by Inco's wholly owned subsidiary, VBNC. Inco is engaged in surface exploration of the underground deposits that will provide information to be factored into an analysis of the underground resources.

In October last year Inco spent C\$400,000 to stake 6,884 claims in the Voisey's Bay area. This is the most the company has ever spent in one staking spree. By the end of this year, complying with agreements with the province of Newfoundland and Labrador, Inco will have spent C\$20 million in exploration of the Voisey's Bay lease. Drilling at Reid Brook, for

example, has returned core samples with Ni contents as high as 3%.

Looking further into the future, there is the Garland Lake area, in which there is great interest. Comparing this area, immediately to the south, with Voisey's Bay, Inco's VP of technical services, was quoted by the Globe & Mail last October: "There is some likelihood, and we're pretty excited about it, of us finding a similar type deposit in that area."

After Inco, Cornerstone Capital Resources is the second largest land holder in the Garland Lake area and recently conditionally agreed to Inco completing airborne gravity gradiometry surveys over its Garland project located 30 km southeast of Voisey's Bay. The survey is part of a much larger survey being completed by Inco over its and other companies' property holdings in this area. The survey is designed to explore for favourable troctolitic rocks similar to those which host the Voisey's Bay deposits, and potentially has the capacity to directly detect large shallowly buried accumulations of massive sulphides akin to magmatic Ni-Cu-Co deposits at Voisey's Bay. Inco completed a significant amount of staking in the Garland Lake area last year.

Site construction work in the gathering gloom of an afternoon in December 2003.



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A Cat truck on a pit haul road with the concentrator in the background.

The survey is planned to be completed in stages during the first half of 2006. Survey parameters have been chosen by Inco and include a gravity gradiometer, a gravimeter, a magnetic gradiometer, and a LIDAR system. Cornerstone's Garland property is expected to be covered by 314 line km of surveying as part of the larger Inco survey.

Operations up and running

The first phase of Voisey's Bay – the open pit and concentrator in Labrador and the hydrometallurgical demonstration plant in Argentina, Newfoundland, plus transport and handling facilities – has cost \$920 million, over a 35-month construction period. SNC-Lavalin/BAE-Newplan was the EPCM contractor for the mine and concentrator. SGE Acres and Hatch working together, as SGEHatch, was the EPCM contractor on the hydromet demonstration plant at Argentina.

SNC-Lavalin was awarded its contract in March 2003, to build an open-pit mine, a 6,000 t/d mill, a permanent accommodations complex and port facilities. While the contract called for first concentrate shipment in July 2006, VBNC asked for an accelerated schedule so the first shipment was ready in November 2005, six months early. "The client had a legally binding agreement with the Province not to ship concentrate from the mine until the hydromet demonstration plant in Argentina was ready to test it," said Oraham Hedow, Project Manager.

"The SNC-Lavalin team worked hard to accommodate the client while not

compromising quality and safety. They knew that if VBNC was not able to ship first concentrate in November, it would have to wait until mid 2006 due to an agreement with the LIA." The team rose to the challenge, and the project did indeed come on stream a full six months ahead of schedule.

"I believe the success of the project was due to our integrated and transparent project team, which continuously innovated during all phases of the project," said Hedow.

"This was particularly evident in the marine transportation of equipment and materials in a very short shipping season, which was key to meeting construction schedules."

At the same time, an industry leading health and safety record in the face of extreme winter conditions was achieved, with seven million person-hours worked on site with a lost time frequency rate of 0.36, compared to the construction industry average of 3.8. The environmental results were equally good: 258 construction permit applications were submitted and approved by Environmental Management Board and Government, and there were no significant environmental incidents during the construction phase of the project.

In the spirit of local content and innovative thinking, Iskuetueu-ABB, the joint venture between Iskuetueu, an aboriginal limited partnership and ABB, a leader in power and automation technologies, was contracted to provide the maintenance services to VBNC over a six-year period. Iskuetueu-ABB offers a rare combination of local experience and global expertise. Iskuetueu-ABB provides a maintenance culture that drives OEE (Overall Equipment Effectiveness). ABB brings

proven implementation methodology that ensures that unreliability is addressed with the most modern techniques and tools. One of the unique approaches implemented at VBNC is the Competency Development Program (CDP) where each maintenance employee has a specific personal development programme that helps them complete a quality job, safely and right the first time. In VBNC, the CDP approach identified some 1,200 specific training programmes required for the maintenance operations to be successful.

Iskuetueu specializes in construction and operations support for industrial projects in Labrador. Through Iskuetueu, the joint venture brings a profound understanding of the business environment, industry needs and regional culture. As a First Nations owned corporation, Iskuetueu provides Inuit and Innu project managers and qualified electrical and mechanical maintenance technicians, supporting the commitment by VBNC to develop and employ a local Aboriginal workforce. Through ABB, a leader in power and automation technologies, the joint venture brings a global perspective and worldclass resources. Headquartered in Zurich, Switzerland, ABB has 102,000 employees in 100 countries, including 25 locations in Canada. That enables the joint venture to draw upon leading world experts, when needed, to ensure the highest quality results.

Hatch has played several roles in Voisey's Bay from its inception in 1999, including assistance in planning pilot-plant test work; studies on the flowsheet optimization; residue disposal; and the Argentina EPCM contract. In 2003 Hatch was assigned to review and update the process data for the Argentina plant. Consolidation of existing test and investigative work was an important step in developing the demonstration-plant flowsheets. The work also helped with understanding the full scope of the commercial plant and included process-flow diagrams, equipment list, equipment sizing, general arrangements for the plant, operating and design factors, and determination of consumption of reagents and other consumables. Hatch also monitored test work on concentrate from Voisey's Bay.

The demonstration plant in Argentina started up on October 20, 2005. This continues work already started at the mini-pilot plant in Inco's Sheridan Park research facility. With financial support of C\$60 million from Technology Partnerships Canada, Inco launched an approximately

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The hydromet demonstration plant is an 8td facility that is 1/100th the scale of the planned commercial plant.

C\$200 million research and development programme in 2002 to confirm the commercial application of hydromet, to treat Voisey's Bay nickel concentrates – basically confirming that pressure oxidation leaching can be used commercially on nickel sulphide concentrates. The mini-pilot programme validated the chemistry, established a workable flowsheet and generated information to begin detailed engineering of the demonstration plant.

At the Argentia opening Inco Chairman and CEO Scott Hand said: "Our hydromet programme represents one of the most significant R&D investments in Canada. Hydromet technology offers a cost-effective and environmentally friendly alternative to conventional smelting and refining which will help place the Canadian mining industry at the forefront of the development of this processing technology."



Inco is developing hydromet technologies for Voisey's Bay in four stages: the bench-scale laboratory testing, which has been completed; the operation of a 1/10,000 scale mini-pilot plant, which began in 2003 and was completed in June 2005; the operation of the 1/100 scale Argentia demonstration plant; and hydromet's final application in a commercial plant environment. The commercial plant, using this technology, would be built in Newfoundland and Labrador.

Hydromet is more economical in capital and operating expenses, more energy efficient, and more environmentally friendly, eliminating the sulphur dioxide and dust emissions associated with a conventional smelter. The demonstration plant phase should conclude in late 2007, at which time the assessment of the technical and economic feasibility of using hydromet technology to treat Voisey's Bay nickel concentrates at the commercial processing plant will be complete. Construction of the commercial processing plant would begin in 2009 and be completed by the end of 2011.

The stripping ratio of the Ovoid pit will average 1.25:1 over its life. It is a very conventional, fairly small-scale open pit, which will be mined from 35 benches, each 7.5 m high, taken in a single pass. Terex Reedrill SK units, two primary and one secondary diesel powered drills equipped for cold weather conditions, drill the blastholes. The main loading shovel for overburden and ore is a Hitachi 1900, loading three Cat 777 haul trucks. These are supported by a number of other Caterpillar mining machines, including a 992 wheel loader for back-up, three D9 tractor dozers and a 385 backhoe.

It is important to restrict the oxidation of the sulphide ore once it has been broken, so the aim is to keep the inventory of stockpiles etc. to just a two-week holding. The concentrator itself is based on a pretty conventional flowsheet centred on the flotation circuit. However, its products are not so conventional. It will produce three different concentrate qualities until the full commercial hydromet facility comes on stream. High-grade nickel concentrate (24% Ni and 0.5% Cu) goes to Inco's Thompson smelter in Manitoba. The middlings concentrate (14-16% Ni and 4-6% Cu) goes to Inco's Copper Cliff smelter in Ontario. High-grade copper concentrate (30% Cu and 0.5% Ni) is sold to custom smelters. It is intended that this latter will

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remain the situation, while the two nickel concentrates will undergo hydromet processing once that full-scale facility is operational.

FFE Minerals supplied the 1.07 x 1.8 m gyratory crusher, while Outokumpu Technology supplied one 6.7 m diameter inside shell by 2.74 m effective grinding length grate-discharge SAG mill and one 4.9 m diameter inside shell by 6.7 m flange-to-flange length trunnion overflow discharge ball mill with discharge trommel screen. A McLellan Equipment mill liner handling machine removes and places shell, grate and end liners of the inner surfaces of the SAG. This is a completely self-propelled, four-wheel steering unit. It features direct acting hydraulic controls for all boom motions. There is a variable speed power trolley for liner transport into and out of the mill. Metso Minerals supplied two vertical stirred concentrate regrinding mills complete with product separating tanks, drive motors and gear reducers, drive guards, liners, mill control systems and skid-mounted lubrication systems. Metso also supplied one vertical stirred lime slaking mill complete with product separating tank, vapour hood, feed pre-mix chamber, wet scrubber and fan, motors and drives, drive guards, liners, mill control system and skid-mounted lubrication system. Outokumpu Technology also supplied a particle size analyzer and on-stream analyzer.

The 22 38-m³ Dorr-Oliver Eimco flotation cells comprise three aeration cells, seven rougher flotation cells, seven scavenger flotation cells, and five scavenger cleaner flotation cells. The 26 8.5-m³ flotation cells from the same manufacturer comprise nine rougher cleaner cells, nine copper-nickel separator flotation cells, four copper scavenger flotation cells, and four scavenger recleaner flotation cells. There are also two 3.5 m diameter and two 3.1 m diameter column flotation cells from MinnovEX Technologies. Concentrate is dried in four Larox pressure filters.

Oldenburg Group supplied a BF-41C-20-88S semi-mobile feeder breaker as a portable crushing plant. This skid-mounted unit is used to reduce the size of agglomerated nickel ore concentrate during the ship loading process. The feeder breaker receives concentrate at up to 1 m input size and reduces it to 100 mm for transport on belt conveyors at a variable rate of 0-400 t/h. The unit is equipped with a receiving hopper that

allows wheel loaders to deliver the nickel concentrate. The variable speed hydraulic drag chain conveyor carries the material through the rotary pick breaker which reduces the material size, and then discharges the sized concentrate to the downstream belt conveyor for ship loading. The unit can easily be relocated by disconnecting the power cable, towing the unit to the next location and simply re-connecting the power. This feature is allowed because all controls and drives are mounted on-board the machine.

Hydrometallurgy

In the process, a finely ground nickel-cobalt-copper concentrate in a pressurized vessel at 150°C will react with oxygen and water to produce an impure solution of nickel, cobalt and copper. This solution will pass through a number of chemical purification steps ending with removal of impurities and separation of nickel, copper and cobalt. The copper and cobalt will be recovered as by-products. The nickel will be recovered by electrolysis as high quality electronic nickel product suitable for market. The waste solids



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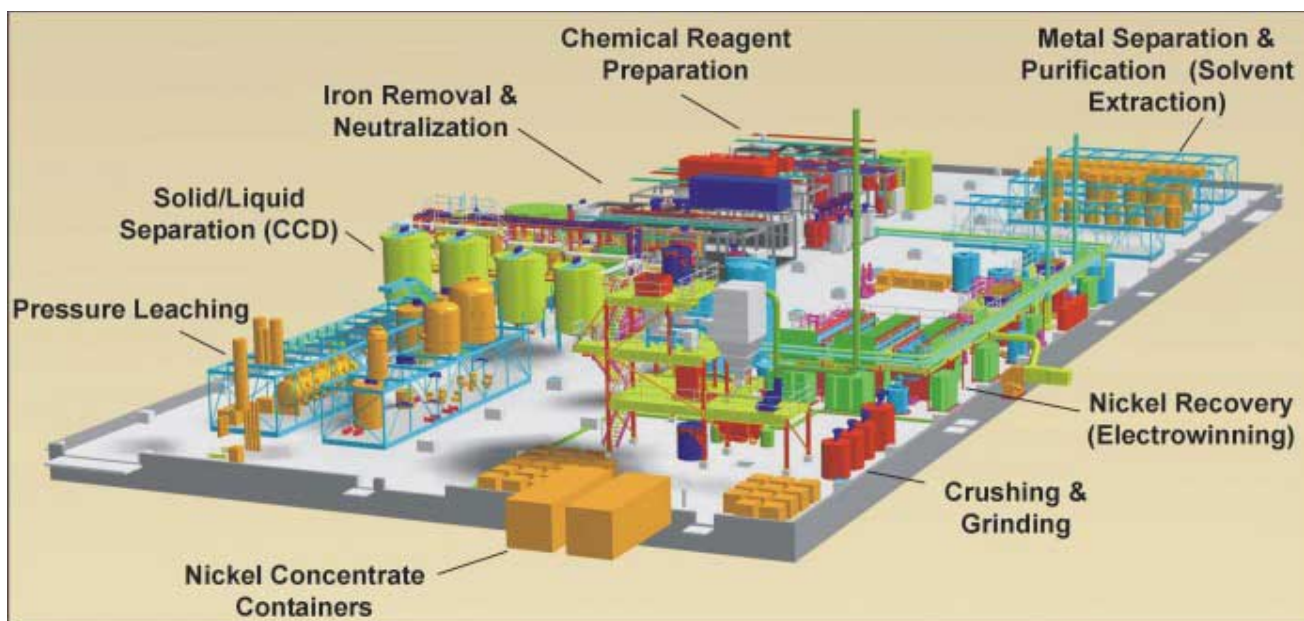


Diagram of the planned hydromet demonstration plant.

from the process will be neutralized with lime and deposited in a specially designed disposal facility. All water leaving the plant will be processed to remove contaminants.

Argentia will prove and fine-tune all processing steps to confirm technical and economic viability and assist designers in the selection of the most appropriate materials of construction and specification of major pieces of equipment. It is an innovative hydrometallurgical process in which pressure leaching of nickel sulphide concentrates is followed by direct nickel EW.

Obviously hydrometallurgy has a major environmental advantage over conventional smelting since most of the waste products from the process are formed as solids, which can be easily contained. Comparatively, conventional smelting converts much of the waste sulphur to gaseous sulphur dioxide, which must be scrubbed from the stack gases. Voisey's Bay sulphides will be transformed into elemental sulphur, which together with iron oxide form the solid residue. The residue will also contain gypsum and unleached rock minerals. It will be stabilized by neutralizing and which will be stored in double-lined containment ponds for the demonstration period.

Argentia is an 8-t/d demonstration plant that receives both a mixed high-grade nickel and a middlings concentrate (-14 mesh), in separate 2-t bags. First the concentrate goes through a McLanahan roll crusher, to break up any lumps formed during transportation, followed by two stages of grinding in a Quinn Process repulping ball mill and two stages of fine grinding in Metso tower mills, to reduce it to minus-20 micron. The roll crushing system accepts nickel concentrate with a maximum lump size of 100 mm and reduces it to a maximum product size of 12.5 mm. Quinn's contract encompassed the design, fabrication, assembly, testing and supply of one complete overflow discharge ball mill mounted on a steel frame. The drive included motor, speed reducer, gear train and/or V-belts. It includes a trommel discharge screen and pumpbox. Typical feed material is high and middling grades of nickel sulphide concentrate at a maximum size of 12.5 mm. The nominal feed rate is 335 kg/h. The ball mill maximum product particle size is 150 micron. The fine grinding tower mills, downstream of the wet ball mill, grind the 60% to 65% w/w nickel concentrate slurry from the ball mill. The feed slurry material is corrosive. Such slurries are normally at pH 3 or lower and may contain dissolved copper and nickel in solution strengths of up to several hundreds of mg/litre. Thus the equipment is designed to resist corrosion and avoid contact of all external components and surfaces with the feed material

The pressure leach circuit's autoclave, where the metals are leached into solution by acid under pressure, is the heart of the



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MV arctic Ice Probe in Anaktalak Bay in February 2005. VBNC and the LIA have a shipping agreement that addresses all aspects of marine transportation into and out of the bay. LIA accepted that VBNC has to have winter shipping in order to get supplies and materials into Voisey's Bay, and VBNC accepted that it had to put a plan into place to mitigate any impact shipping activity in Anaktalak Bay may have on Inuit hunting, recreation and travel.

process. The autoclave supplied by All-Weld Co is a horizontal carbon steel vessel with a 1.5 m inside diameter. Its internal design pressure is 1,535 kPa at 1,500°C. It is internally lined with an acid resistant membrane and equipped with Ekato agitators. Oxygen in the autoclave oxidizes most of the sulphur in the sulphides to molten elemental sulphur. Some will be oxidized further to produce the acid required to dissolve the metals. Excess acid formed is later neutralized by adding limestone to form gypsum, which separates from solution. The oxygen also reacts with contained iron, which at the final pH of 3 forms solid iron oxide. Both sulphur and iron oxide are then separated as waste residue from the metal bearing solution by counter-current decantation.

A two-step process using limestone, hydrated lime and oxygen removes residue from the metal solution, which is then purified and extracted into separate solutions by solvent extraction. Finally, copper, cobalt and nickel are recovered separately as finished metal cathode products by electrowinning. Three tanks, each containing five 1-m² sheets recover the nickel. The sheets take seven to ten days to plate, and are 99.9% pure nickel.



Argentia automation

Emerson Process Management was chosen to automate the Argentia plant. This included installing Emerson's PlantWeb digital plant architecture. The company's digital approach uses an open, standards-based FOUNDATION fieldbus network to connect intelligent field devices and Emerson's DeltaV digital automation system. PlantWeb diagnostics in the intelligent field devices continuously monitor the health of the process, instruments, and equipment, and inform personnel of any issues that need attention. It also provides guidance for operators and maintenance staff to address potential

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problems before they diminish process performance or cause shutdowns.

The PlantWeb architecture of the plant has more than 100 pH measurement loops that are critical to plant throughput and performance. To achieve the necessary precise pH control, Emerson's advanced Rosemount Analytical Solu Comp Xmt transmitters with built-in digital diagnostics continuously monitor device and process health.

The digital PlantWeb network includes Rosemount pressure and temperature transmitters and magnetic flow meters, Fisher control valves with FIELDVUE digital valve controllers, and Rosemount Analytical

conductivity instruments. The AMS Suite: Intelligent Device Manager asset optimization software will gather and use diagnostic information from the smart field devices. The AMS Device Manager also receives PlantWeb Alerts that are generated when issues arise. The Alerts inform of impending situations, and give guidance to operators and maintenance personnel to help them avoid interruptions and maintain high plant availability.

John Casson of VBNC explained: "In addition to using PlantWeb in the plant, we are using the DeltaV system at the mine and concentrator." PlantWeb architecture allowed substantial savings in installation

and commissioning costs while enhancing diagnostics and making the entire system easier to configure, commission, and maintain.

The DeltaV system offers such advanced control solutions as fuzzy logic, neural networks, and multivariable process control. "One of the key deliverables from the demonstration plant is a comprehensive and accurate record of all process and production parameters, including instrumentation performance data, as the plant moves through its operational phases," Casson said. "The DeltaV system, in conjunction with the PlantWeb, DeviceNet, Asi, and fieldbus technologies, serves this need."

The plant uses thickening and clarifying technology from Dorr-Oliver Eimco, including rakes, rake drive, rake lifting mechanism and rake support bridge for ten thickeners and one clarifier. The sizes range from 1.6 m diameter to 4.2 m diameter, with overflows ranging from 2 to 4 m³/h. Dorr-Oliver Eimco provided the design and detailed drawings for the thickener/clarifier vessels so that the thickener tanks could be fabricated by local companies.

Concentrator tailings are pumped 9 km east to a 140-ha tailings impoundment area made from Headwater Pond, 30 m deep, with 12-m-high dams at head and mouth. Pipeline Systems International designed the 200-mm diameter, graduated, high-pressure tailings line, which is continuously welded to prevent leaks and it has a leak detection system. All pipelines (water and tailings) have been heat-traced to prevent freezing. The Ovoid pit will put 15 million m³ of tailings and waste rock (containing 0.2% S) in the impoundment over its life. This will be deposited beneath 4 m of water to prevent oxidation. Water from the impoundment will be reused in the concentrator.

Voisey's Bay will help increase Inco's production levels by about 35% by 2009 from the 2004 level of 237,000 t of nickel. Inco's output this year is expected to be 245,000 t of nickel comprising 33,000 t from the Manitoba operations, 50,000 t from VBNC, 75,000 t from PT Inco and 87,000 t from the Ontario operations. By 2009, the PT Inco's Indonesian operations are expected to be the largest, yielding 91,000 t, followed by 86,000 t from Ontario, 60,000 t from VBNC, 53,000 t from the new Goro mine in New Caledonia and 30,000 t from Manitoba, for a total of 320,000 t. *IM*

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