Canadian Army Radar Association (CARA)

Lieut. Ken Bell / Canada. Dept. of National Defence / Library and Archives Canada / PA-190495

LAST ONE

Ahead of British and American counterparts, Canadian engineers developed the first anti-aircraft-guiding radar, deployed in July 1942. Luckily, a single unit remains largely intact.

"Gentlemen...this piece of anti-aircraft equipment is the MZPI—Micro Zone Position Indicator—known affectionately to Bird Gunners as, THE ZIPPY."

The source of those words was a Sergeant, Assistant Instructor of Gunnery, who wore a red-topped peaked cap and was referring to the post-war Canadian-built tactical control anti-aircraft radar, as he faced a fresh cadre of Royal Artillery National Service officer cadets about to begin the 10 weeks corp training segment of a 16-week course at MONS Aldershot, in May 1950.

A few months later, I was on a course at the School of Anti Aircraft Artillery, Manorbier, Wales where I received more detailed training on the MZPI radar prior to qualifying as an Operators Fire Control Instructor . By this time I was referring to the ZIPPY as the AA Radar No 4 Mk 6, before later versions morphed into the AN/ MPS/ 501B.

The army probably got poor value for the training invested in me, since following completion of my National Service, less than two years later, I was beginning a new life in Canada. Memories of radar came into my mind some 40 years later, when I found myself taking a lunchtime stroll with a client in the Leaside district of Toronto and it was pointed out to me that we were opposite the site where Research Enterprises Ltd (REL) had been located. I recalled without hesitation, seeing that name stamped on the serial number tags of the MZPI radars deployed in the training area back in my National Service days. This chance encounter with the REL factory site in Leaside prompted me to see what might be available on the internet. At that time, I got only one hit ! And that was on a website "Points of interest along lost streams."

Upon full retirement in 2002, I made a more serious effort to find out more about Research Enterprises Ltd and to see whether any MZPI radar cabins had survived in Canadian museums or in private collections. It quickly became evident from published material that the MZPI radar was developed and manufactured using the experience gained from its predecessor, the gun-laying anti aircraft radar known as the GL III (c),which was the first mobile microwave frequency radar to be put in to mass production anywhere in the world. As I was to discover in further research, the development of the GL III (c) by the Radio Branch of the National Research Council and its manufacture at Research Enterprises Ltd in Leaside, Toronto is arguably one of the most remarkable achievements of Canadian scientists and engineers during WW II.

In September 1939, the Radio Section (as it was called) of the NRC had only a handful of employees familiar with the technical details of the work carried out by Robert Watson Watt on RDF (Radio Direction Finding) – the figures from archival sources vary from two to five individuals knowledgeable in this area. By the time WW II ended, the Radio Branch of NRC had very nearly 300 technical staff who had developed or adapted from existing designs a wide variety of military radars.

The Accurate Position Finder (APF) trailer of the GL III (c) gunlaying radar system on display at the Royal Canadian Artillery Museum at CFB Shilo, Manitoba. Photo Credit: *Cal Gibson.*

Of particular interest to IEEE members, the president of the NRC in the period before WW II was Maj Gen (ret) Andrew G. L. McNaughton, who was both a distinguished soldier and scientist. He recognized, before others did, the significance of Watson Watt's work and it was Gen McNaughton who laid the groundwork that made it possible for the Radio Branch to play such an important role in the development of military radars. It is fitting that IEEE Canada recognized this and his other contributions to the engineering profession by creating the A.G.L. McNaughton Award, given annually to members of the profession deserving of recognition.

Of the military radars the Radio Branch developed/adapted, the most elaborate and unquestionably the most impressive was the GL III (c) microwave radar, which -- by good fortune -- we now know a last unit remains largely intact. The device was conceived following the disclosure of the first practical cavity magnetron by the British Tizard Scientific Mission to Canadian and U.S. scientists in August 1940. This critical technological leap resulted in a compact device capable of gener-

STANDING

by Brian Mendes

ating ultra high freqency radio waves (centimetric) at power levels higher than had been achieved with vacuum tubes. Developed by John Randall and Henry Boot of Birmingham University (see sidebar next page), the magnetron opened possibilities for radar in applications impossible using power transmitters in the metric waveband.

Prior to the disclosure of the cavity magnetron, the Radio Branch had been adapting essentially British designed radars for manufacture by the (yet to be built) Crown Corporation factory, Research Enterprises Ltd in Leaside. The decision taken following the visit of the Tizard Mission to develop a centimetric gunlaying radar based upon the cavity magnetron had an enormous impact on the work underway at the Radio Branch. There was no history for dealing with the problems associated with very high energy centimetric wavelength equipment and techniques had to be invented as development took place. This required very close cooperation with the production staff at Research Enterprises Ltd. In general, development of new products was the responsibility of the Radio Branch and production was the responsibility of REL. This was difficult to follow when such an unfamiliar technology was being developed. The REL production team had to contend with over 300 design changes as the production line was being layed down. This and other accounts are well documented in the publications cited as source material by the author.

The interior of the Zone Position Indicator (ZPI) cabin of the GL III (c) on display at CFB Shilo. Photo Credit: *CARA.*

The Radio Branch did enjoy very close cooperation with the British Radar Experimental Establishments throughout the development and later with the Americans, once they had the Radiation Laboratories underway. This occurred some time after the Radio Branch had produced a prototype centimetric gunlaying radar that met the performance specifications for a GL Type 3 radar.

At the time of the visit of the Tizard Mission in August 1940, the threat of a major air assault on Great Britain was very serious and the need for a GL III type gun-laying radar received a high priority. As a result, the decision was taken to proceed simultaneously with development projects in Canada, the USA and the UK, all working from essentially the same design specifications. It was the Canadian team of scientists and engineers from the Radio Branch of the NRC and Research Enterprises Ltd that put the first mobile centimetric gunlaying radar into mass production. The decision to use the cavity magnetron came on October 23, 1940; full demonstration of the assemblies was June 27, 1941. The July 23, 1941 full demonstration for US visitors gave rise to the statement by the chief engineer of Westinghouse Corporation..."that his company would not have believed that what we (Radio Branch of NRC) had done in nine months, could have been done in two years." It is this achievement that places the GL III(c) project among the finest for Canadian Science and Industry.

The GL III(c) system actually comprised two radars, an acquisition radar for spotting targets, the Zone Position Indicator or ZPI. This was a metric wavelength set utilising many sub units similar to those in existing radars. The other component was a 10 centimeter wavelength precision tracking radar providing continuous positional data for control of the anti aircraft guns. This was the unit that required the most development work and was referred to as the Accurate Position Finder (APF).

The time period for the project to progress from its inception to the placement of production quantity orders is well illustrated by the following listing of key dates

Five preproduction prototypes were built in the NRC shops before the first production models came off the line at the REL Leaside factory in July 1942. By the end of 1942, 314 sets had been delivered , many of which were deployed on UK anti aircraft gunsites. A total of 667 GL III(c) radar convoys were manufactured by REL under the Lend Lease contract.

Most of the design flaws which accompanied such a rapid timeline from the design stage to mass production were remedied in the MZPI (designed in 1944) which was a centimetric wavelength version of the ZPI unit of the GL III (c). It was judged by both the Americans and the British to be the best sweep search surveillance radar available in the immediate post war years, and as a result the British purchased the MZPI for deployment with its mobile and static anti aircraft gunsites.

Early Years of Canada's Foray into Radar

1931–Radio Section NRC established

1935–R.A. Watson Watt demonstrates detection of aircraft for British Air Ministry using the BBC Daventry short wave radio transmitter (birth of RDF)

Maj Gen (ret) Andrew G.L. McNaughton appointed new president of the NRC

1937–First of 20 Chain Home (CH) RDF stations constructed around UK coast

1938–McNaughton consults with DND about detecting aircraft by electrical means

1939–Dr. John Henderson of Radio Section NRC sent to UK to be briefed on radar developments, on advice of McNaughton

Sept 3rd–WW II declared.

The author started investigating this story in 2002 with the object of seeing whether an MZPI could be located in Canada, not knowing of its predecessor, the GL III (c) and the remarkable chain of events leading to it being the first mobile centimetric radar to be put into mass production during WW II. As the facts

The serial plate of a GL III (c) cabin. A total of 667 GL III (c) convoys were manufactured at the Research Enterprises Limited facility in Toronto. Photo Credit: *CARA* were revealed in published material and contacts made on the internet it was assumed that, since only one or two MZPI gutted cabins were known to exist, it was assumed that none of the GL III (c) units, built during WW II had survived—a fact also assumed to be true by CARA veterans (Canadian Army Radar Association). That was until I received word from a post war serving RCEME warrant officer who recalled seeing (sometime in the 1980s) two cabins parked in the storage yard of the Royal Canadian Artillery Museum, Shilo, Manitoba that he believed were the APF and ZPI cabins of the GL III (c). When the cabin interiors were inspected, it was surprising to see how much of the original pre solid state electronics was still in place. In the post-war period, radio ham enthusiasts and other collectors stripped the interiors of such cabins for parts when military radars were disposed of after being declared surplus. As an aside, cathode ray tubes from units such as this were used by the electronics D.I.Y. crowd of the time to construct televisions during its early days. With the exception of those found in Shilo, WW II radar cabins located around the world have no electronics in place.

This places the GL III (c) cabins in a unique category and it is safe to assume that no other examples exist with so many of the original components still in place. The RCA Museum has indicated its support for preserving the interiors of the cabin – and perhaps even restoration – should funding become available.

Cavity Magnetron

The cavity magnetron was the first practical device for producing powerful ultra-short radio waves (microwaves). It was developed in late 1939 by John Turton Randall and Harry Boot at Birmingham University.

Like other earlier magnetrons, it was a vacuum tube with a cylindrical anode enclosing a magnetic axial thermionic cathode, having a magnetic field directed along the axis. However, the addition of circular cavitities inside the vacuum allowed radio waves to internally reflect and build amplitude, until being released in powerful bursts into a coupling inside a cavity. In addition, Randal and Boot placed the anode inside the vacuum envelope and not within the vacuum region. The magnet gap could therefore be reduced and the anode more efficiently cooled.

The ability of the device to produce such powerful radiation at such small scale made adaptation for use on aircraft feasible. The same device is also the ancestor of the magnetron that is used to power every microwave oven.

The magnetron brought to Canada in 1940 by the British Technical Mission, led by Henry Tizard. Photo Credit: *Canada Science and Technology Museum; artifact # 1969.0482.*

Dept. of National Defence / Library and Archives Canada

The Zone Position Indicator (ZPI) unit of the GL III (c) spotted targets. The design was adapted from earlier British systems.

Acknowledgements

The author acknowledges the use of material from the following sources :

Radar Development in Canada: The Radio Branch of the National Research Council of Canada 1939-1946, by W.E.Knowles Middleton (1981)

No Day Long Enough : Canadian Science in World War II, edited By George. R. Lindsey

The Mackenzie-McNaughton Wartime Letters, edited by Mel Thistle

The Science of War—Canadian and Allied Military Technology during World War II, by Donald H. Avery

Scientists at War, by Wilfred Eggleston (1950)

Top Secret Exchange—The Tizard Mission and The Scientific War, by David Zimmerman

National Research Council of Canada, The War History of The Radio Branch Report; No. ERA 141 (1948)

An Exhibition of Radar and Associated Electronic Developments, prepared by the Radio Branch of the NRC. CA-NR- 4429 (Nov. 1945)

History of the Department of Munitions and Supply: Canada in the Second World, by J. de N. Kennedy (Nov. 1950)

The Development of Research Enterprises Ltd, by W. E. Phillips, RG 28A vol 17, Library and Archives, Ottawa

"Research Enterprises Ltd. And Wartime Emergence of Radar,' by Frank H.R Pounsett, *IEEE Canadian Review*, March 1990

The Invention that Changed the World, by Robert Buderi

"The Invention of the Cavity Magneton and its Introduction into Canada and the USA," by Paul. A. Redmond, *Physics in Canada*, Nov./ Dec. 2001

"Origins of Radar-based Research in Canada, by Don Moorcroft" (Physics: University of Western Ontario—radar history)

Key Dates in Development of GL III (c) Gun-Laying Radar

Oct 23 1940
Decision to use the cavity magnetron

Mar 17 1941
Demonstration of aircraft location at 17,000 yards. (specification acceptable was 14,000 yards)

June 17 1941
Full demonstration to authorities

June 24 1941
Dr. Mackenzie's discussion in Washington with Commonwealth Scientific Office on an order for 400 radars under "Lend Lease"

July 23 1941
Full demonstration with US visitors (Field Station in Ottawa).

July 27 1941
$ 26,000,000 order placed for 400 radars (later increased to 600)

Dec 17 1941
Japan attacks Pearl Harbor.

July 1942
First delivery of production models GL III (c) from REL plant. This being the first centimetric wavelength mobile radar to go into mass production anywhere in the world.

Dec 1942
A total of 314 G L III (c) gunlaying radar sets were delivered before the year end. No models of the British or US designs were in mass production by this time.

Dec 1943
Lend Lease order for 600 sets completed.

A.G.L. McNaughton: engineer, soldier and statesman

Major-General Andrew George Latta McNaughton. Credit: *Vandyk Ltd./Library and Archives Canada/ PA-034110*

Born in 1887, McNaughton studied at McGill University, in 1912 completing his Master's of Science degree with Honours in Electrical Engineering. Working as a consultant before the start of WWI, he published six papers on high voltage electrical phenomenon. In 1914 he enlisted as a militia officer, commanding gun batteries. Employing his engineering mind, he optimized triangulation data from the sound and flash of enemy artillery in accurate survey schemes. His results were extraordinary. Using the techniques he pioneered, Canadian counter-battery destroyed more than 70 percent of the opposing artillery in the week prior to the Battle of Vimy Ridge. By the end of the war, he was in charge of all heavy artillery and counter-battery forces of the Canadian Corp.

Joining the regular army in 1920, McNaughton was rapidly promoted, becoming Chief of the General Staff in 1929, holding that position until 1935 when he was appointed President of the National Research Council. It was during the early to mid-1920s he developed a working model of a cathode ray detection finder—the direct forerunner of radar.

McNaughton had various commands in WWII, then was appointed Minister of Defence in 1944. Following the war, he was appointed Canadian Chairman of the Canada-United States Permanent Joint Board on Defence, and in 1946 became Canadian representative to the United Nations Energy Commission and head of the Atomic Energy Control Board of Canada. In 1948, McNaughton was appointed permanent delegate of Canada to the United Nations and Canada's security council representative. He became a Commissioner of the International Joint Commission in 1950, and shortly after, named its Canadian Chairman, evaluating amongst other projects development of the St. Lawrence River for navigation and power.

A more full account of Andrew McNaughton's remarkable contributions can be found on-line in Issues 9 and 10 of the *IEEE Canadian Review*, in a two-part piece by Ted Glass. Mr. Glass skillfully condensed John Swettenham's three-volume biography *McNaughton*. Still a public figure of interest, McNaughton's latest biography was published in 2010: *The Politics of Command*, by John Rickards.

Research Enterprises Ltd: history-making engineering

Research Enterprises Ltd (REL) was a crown company originally conceived in 1940 to manufacture optical grade glass for use in military binoculars, gun sites and other instruments along with other items being developed or adapted by the NRC. Very soon after construction began on the factory site, the decision was made to expand the plant to include the production of radar sets for the military.

Located on 55 acres of land southeast of Eglington Ave and Laird Ave in what is now the Leaside (Toronto) Industrial Park, at its height, the plant had more than 7,000 employees working in the Instrument and Radio Divisions. In total, more than 9000 radar sets were manufactured at REL before operations ceased in September 1946. Today, little remains of the huge factory that was so important to the Allies war effort; an exception to this being the radar building now occupied by Parkhurst Knitting Mills Ltd, a Canadian-owned women's apparel manufacturer.

Hon. C.D. Howe, then Minister of Munitions and Supply, receives a lesson in lens curvature testing at Research Enterprises Limited. Photo Credit: *National Film Board of Canada / Library and Archives Canada.*

Cathode ray tube interiors are prepared at Research Enterprises Ltd. Photo Credit: *Nicholas Morant/National Film Board of Canada/Library and Archives Canada.*

One of the few original buildings left from the sprawling complex that was Research Entreprises Limited. This facility is now the home of Parkhurst Knitwear, a third-generation, Canadian-owned business started in 1926 by Louis Borsook. Originally a hat-making operation, the company now produces knitted women's apparel.

Thomas Ray

Brian Mendes is a retired industrial chemist who spent most of his working life in synthetic fibres related companies. He was born and educated in England. Before emigrating to Canada in 1954, he served his National (Military) Service years in a heavy anti-aircraft regiment of the Royal Artillery where he first became acquainted with gun-laying radar. Many years later he undertook some recreational research into the history of the Canadian radar equipment that he trained on in the military. This article records the findings of his research.