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Use of radiant heaters to prevent icing

by
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Ice buildup on machinery can make locks and dams inoperable and can pose safety hazards to personnel who must remove it. The problem starts with ice accumulation on cables, gears, gates, steel plates, or concrete walls. This ice may be formed by water spray or mist on cold steel, water-level changes, freezing rain, or refrozen melt water. In the past, it has been removed either mechanically by chipping or thermally by using hot water or steam.

Various heating devices, such as heater panels on lock walls, have been used to remove or even prevent this accumulation (see *The REMR Bulletin*, Vol. 11, No. 1, April 1994). More recently, the feasibility of installing radiant (infrared) heaters in areas that are difficult to access has been investigated (Figure 1). Such heaters have been successfully used at Lock and Dam 16 on the Upper Mississippi River in the Rock Island District (Figure 2) and also in the St. Paul District. Not only are such heaters effective in keeping locks and dams functioning, but they also eliminate the need for personnel to climb into almost inaccessible areas to perform a task described as one of the most dangerous that can be conducted around locks and dams.

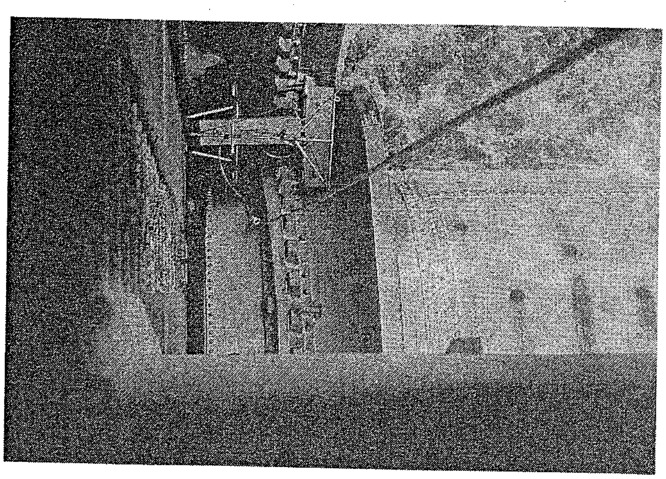


Figure 1. Infrared heaters suspended above a roller gate at Lock and Dam 16. The two heaters in the form of a "T" are directly above the gears

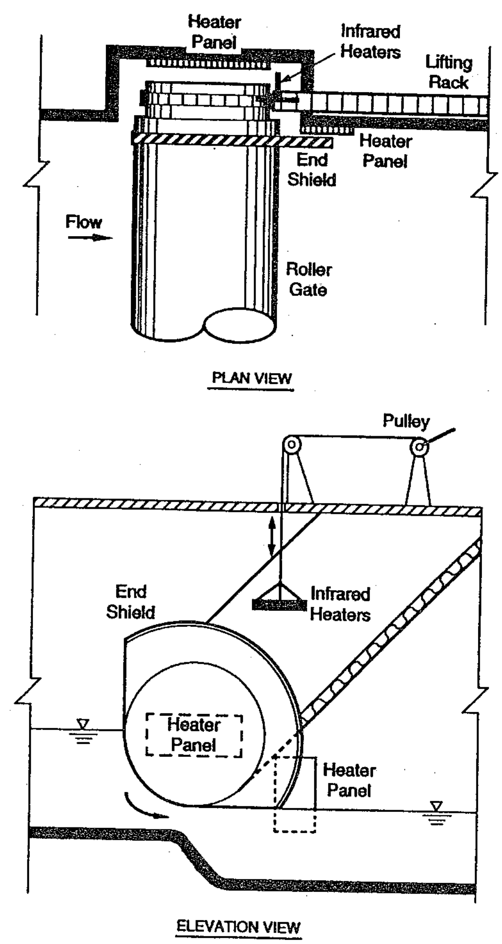


Figure 2. Infrared heaters at Lock and Dam 16

Laboratory tests

Under the REMR Research Program, the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) has conducted tests with infrared heaters. The purpose of these tests was to determine the effects of three variables on heater performance: wind speed, distance between heaters and ice, and ambient air temperature. The test setup is shown in Figures 3 and 4.

The tests were made in a cold room with a fan creating the desired wind speed. Blocks of ice 19 in. long by 21 in. wide and varying between 2 and 3 in. thick were used. Each ice block was placed on either a steel plate or a wood frame suspended beneath a heater. Two load cells measured the loss in weight of the ice as it melted. The differences in melt rates for ice placed on steel plates or wood frames were recorded. Several thermocouples were positioned in the air above the ice, and two were embedded in the ice block. All tests were conducted for a fixed period of time, usually 3 hr, so that the results could be compared. Data were collected every 5 min with a Campbell Scientific data logger and later processed on a computer.

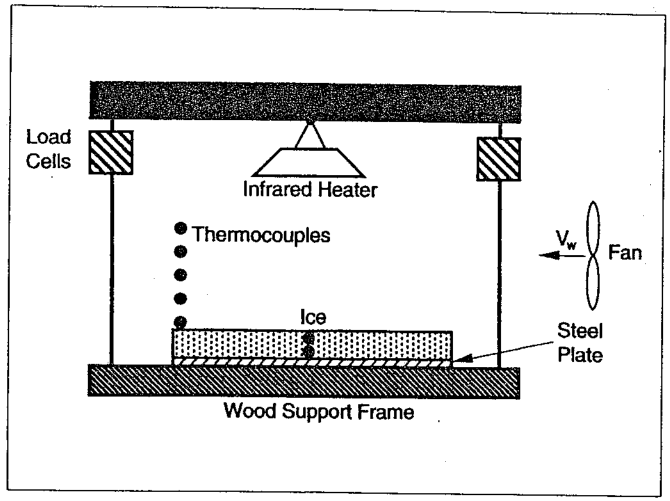


Figure 3. Test setup for laboratory tests

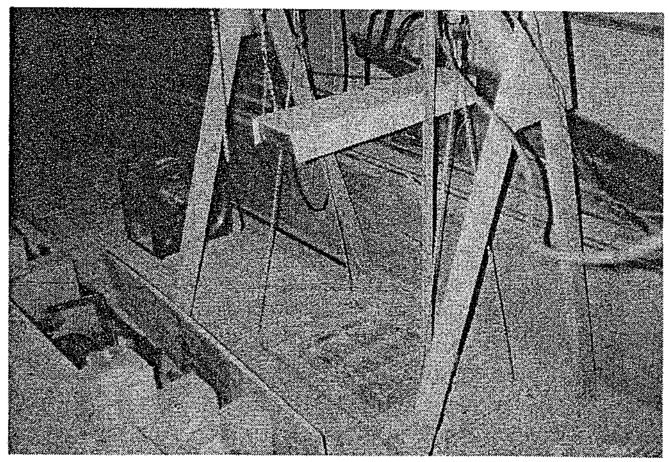


Figure 4. Test setup

Test results

The results of three tests using a 3,000-W heater at 10 °F are given in Figure 5. The effects of heater height and wind speed are clearly indicated. An increase in height from 20 to 40 in. reduced the melt rate by about 75 percent. A moderate wind speed of 10 mph reduced the melt rate by 97 percent at the 20-in. height.

Temperatures in the ice were measured with thermocouples at the midlevel and the bottom of the ice block, and in the air at the ice surface and at various heights above the ice (Figure 6). One test was run with no wind, and the other, with a 10-mph wind (see Figure 5 for melt-rate records). The temperature of the air above the ice rose sharply at the beginning of the test with no wind and stayed above freezing throughout the test. Air immediately above the ice was warmed by radiation absorption. The ice block warmed up until the entire block was at the freezing temperature. Melt water was visible on the surface of the ice throughout the test. About 120 min. into the test, the temperature in the middle of the block went above freezing because the ice had melted away from the thermocouple.

The air did not warm, however, with wind blowing over the ice because of the cold ambient air forced into this space. There was some warming of the block but not to the freezing temperature.

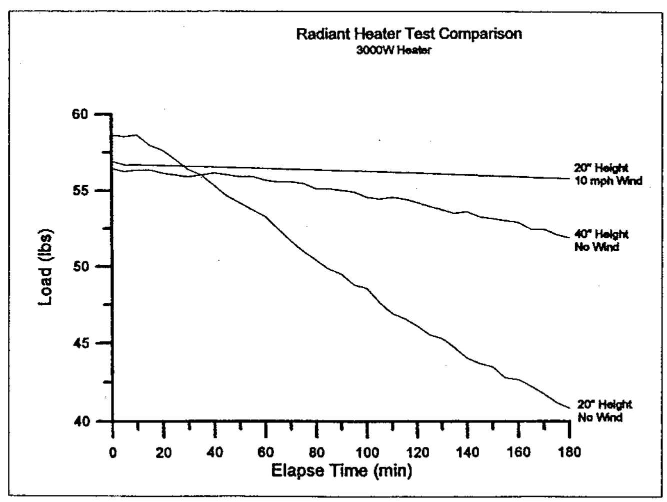


Figure 5. Ice melted as a function of time for three test conditions, tests 1, 6, and 7 with ice on steel

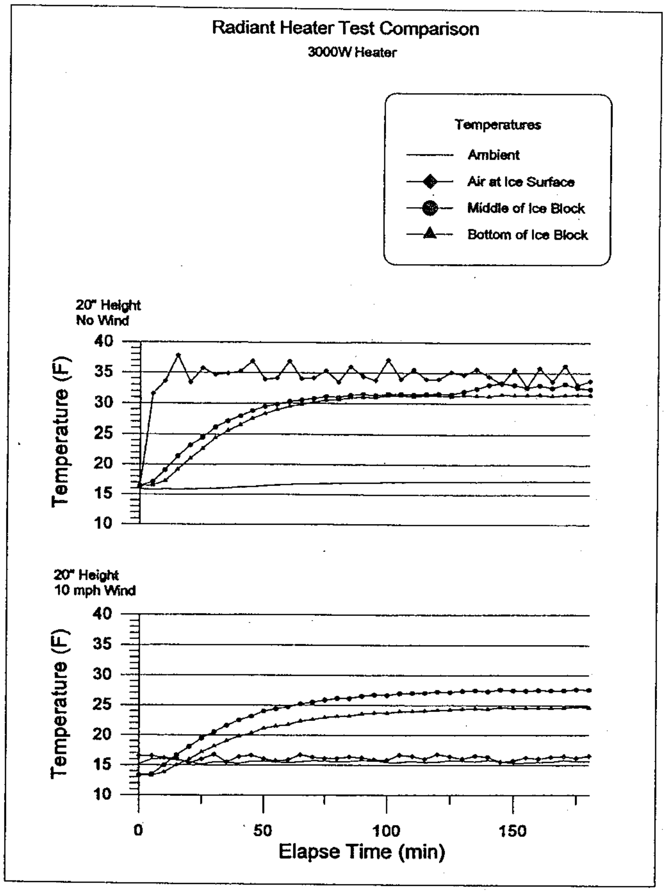


Figure 6. Temperatures in ice block and air during test 1, without wind, and test 6, with a 10-mph wind, for ice on steel

There was a small (0.5 lb) melting of ice in this test, but there was no visible melt water on the ice surface. In this case, it appeared that all of the melted ice was removed by evaporation and sublimation. With no wind, the melt water removed by evaporation was much less.

The test results are summarized in Table 1. For similar test conditions, the numbering of the tests with ice on the wood frame are matched with the numbering of the tests on a steel plate. The melt rate was about the same with and without the steel plate, indicating that heat reaching the steel plate was dissipated into the cold ambient air. It was found that the air temperature affected the melt rate. Comparing similar tests with ice on steel in Table 1, the melt rate at 16 °F (test 7) was about 1.5 times the rate at 7 °F (test 3). This is due to the higher convective heat transfer from the ice surface at colder temperatures which reduces the melt rate.

Heat transfer model

An energy balance on the surface of the ice during a test is illustrated in Figure 7. The incoming infrared radiation (wavelength: 700 - 1,100 nanometers) is Q_{rad}, and the reflected radiation is Q_{ref}. Some of the radiation is absorbed by the ice, Q_{abs}. The amount of radiation absorbed can vary between 50 to 80 percent. When melt water is present on the ice surface, the radiation absorbed can increase to 90 percent. Heat is transferred from the ice surface to the cold air by convection, Q_{conv}. Without wind, this heat is transferred by natural convection, and with wind, it is by forced convection. Heat is transferred from the ice surface to the cold air by evaporation, Q_{evap}, and also by melt-water runoff, Q_{melt}.

The efficiency of the radiant heaters is affected by wind, height, and the geometric shape factor. This shape factor is the fraction of the radiant energy produced by the heater elements which actually reaches the ice to melt it. Considering the geometric shape factor and the measured melt rates with the latent heat required, overall efficiencies ranged from about 5 to 15 percent for these tests.

Field applications

At Lock and Dam 16, two 3,000-W heaters have been suspended above the gears on a roller gate and can be lowered or raised by a wire rope and pulley (Figure 2). During cold weather, they are lowered to about 3 ft above the ice, where the

Table 1. Test Results with 3,000-W Radiant Heater

Test	Air Temperature, °F	Height, in.	Wind Speed, mph	Average Melt Rate, lb/hr
		Ice		
1	16.0	20	0.0	6.44
4	15.5	40	10.0	0.19
6	16.5	20	9.9	0.33
7	17.0	40	0.0	1.42
		Ice on Steel		
1	16.5	20	0.0	6.86
2	8.0	20	5.7	0.19
3	7.0	40	0.0	1.11
4	16.0	40	9.1	0.15
5	8.0	20	0.0	3.20
6	15.5	20	10.0	0.17
7	16.0	40	0.0	1.58
8	7.0	40	10.0	0.09

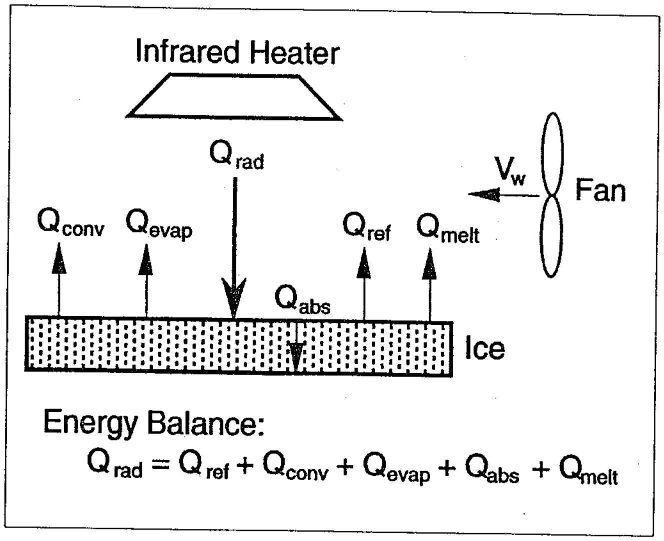


Figure 7. Energy balance on ice surface

ice can be prevented from growing. Care is taken to prevent water spray from getting on the heater elements. Given the required circumstances, ice can grow from 4 to 12 in. around the gear area. This accumulation can be melted off in about a day with the heater setup being used at this facility. The heaters are turned off when the air temperature reaches 32 °F to save on the energy cost.

At Lock and Dam 10, radiant heaters are being used on four roller gates. These heaters are 2,500-W units that operate on 480 V. They have kept the gear area on a roller gate ice free at 0 °F air temperature. Without the heaters, water-level changes cause ice formation in this area.

At Lock and Dam 9, radiant heaters have been placed near the gear area and also around the seals just above the roller gates. Here it is necessary to keep at least one gate operable due to water-level changes.

Based on the laboratory tests at CRREL, the colder and windier the conditions and the farther the heaters are from the ice, the less effective the radiant heaters will be. Under field conditions, there may be little control over these factors; therefore, more time may be required to control icing than is indicated in laboratory tests. In some applications, a wind shield or hood could be suspended below the heater to reduce or eliminate the effect of wind. Another method to improve the efficiency may be to use reflectors to focus the radiant energy on the ice to be melted.

For additional information, call Don Haynes at (603) 646-4184.

News in Brief

James E. McDonald, Structures Laboratory, Waterways Experiment Station, was elected to serve a 3-year term as one of the Directors of the International Concrete Research Institute. McDonald has been the REMR Problem Area Leader for Concrete and Steel Structures since REMR-I was initiated in 1984 and has been the author of numerous bulletin and journal articles and technical reports.

Air-bubbler systems and high-density polyethylene sheets alleviate icing at locks and dams

by F. Donald Haynes, Robert Haehnel, and Leonard Zabilansky
U.S. Army Cold Regions Research and Engineering Laboratory

A total of 37 significant ice problems were identified in a survey of Corps of Engineers projects (Haynes et al. 1993). Some of these problems include ice in the upper approach of a lock and ice accumulation on miter gates, tainter gates, roller gates, lock walls, and machinery. These problems can cause delays or even stoppage of barge traffic. Hundreds of man-hours may be required to restore the facility to normal operations. Lock personnel are often called upon to chip ice off machinery in dangerous situations.

Working under the REMR Research Program, the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) has developed techniques that may be used singly or in combination to eliminate or mitigate some of the ice problems. Panel wall heaters and water jets have been described in previous issues of *The REMR Bulletin* ("Panel Heaters Used to Control Ice Growth Caused by Fluctuating Water Levels" and "Panel Wall Heaters Successful at Starved Rock Lock and Dam, Illinois River," Vol. 11, No. 1; "Heated Water Jet for Melting Ice," Vol. 10, No. 4). The use of infrared heaters is described in an accompanying article in this bulletin. Two additional methods include the installation of air-bubbler systems and high-density polyethylene sheets.

Air-bubbler systems

Air bubbler systems have been installed at some locks and dams with very good results. Details of a bubbler system are given in Engineer Manual (EM) 1110-8-1 (FR). Typically, a 100-psi, 750-cfm compressor is used to supply air to submerged diffuser pipes that have orifices as shown in Figure 1. The supply and diffuser pipes are anchored to the walls and sills of a lock chamber by straps and bolts (Figure 2). A diffuser line is placed in each miter gate recess to flush floating ice out of this area so that miter gates can be fully opened. By fanning the miter gates and operating the recess flusher, ice can be moved out of the recess (Figure 3).

Another diffuser pipe, called an air screen, is one that spans the width of a lock chamber (Figure 4). One air screen is located just upstream of the upper gates to help prevent ice from being pushed into the lock chamber by a downbound tow. Another air screen is located in the chamber just upstream of the lower miter gates to create an area of open water so that the recess flushers can move ice into this area freely; then the miter gates can be fully opened. The alternating operation of the recess flushers and the air screen in conjunction with gate fanning has proven to be an effective technique.

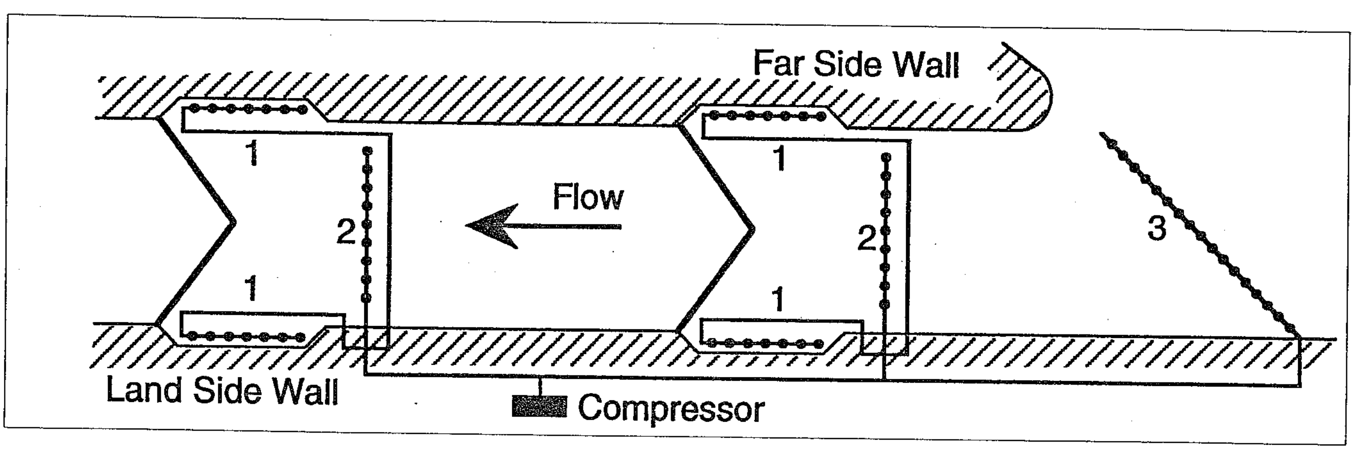


Figure 1. Schematic of lock bubbler system. The numbers identify the various diffusers: (1) recess flusher, (2) air screen, and (3) deflector air screen

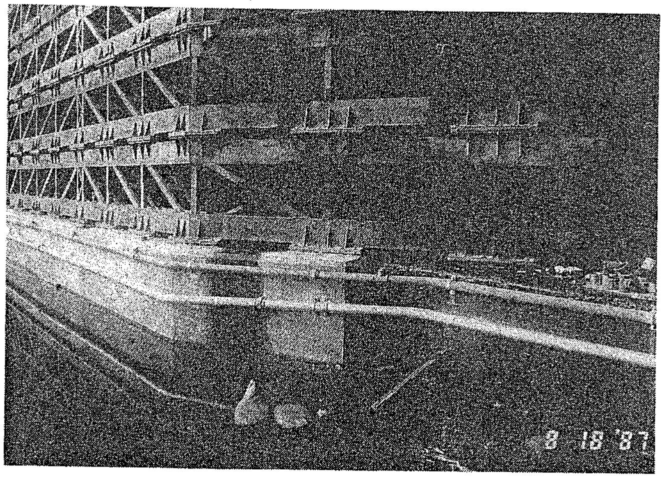


Figure 2. Air supply line and diffuser pipe installed on a lock sill at Peoria Lock and Dam

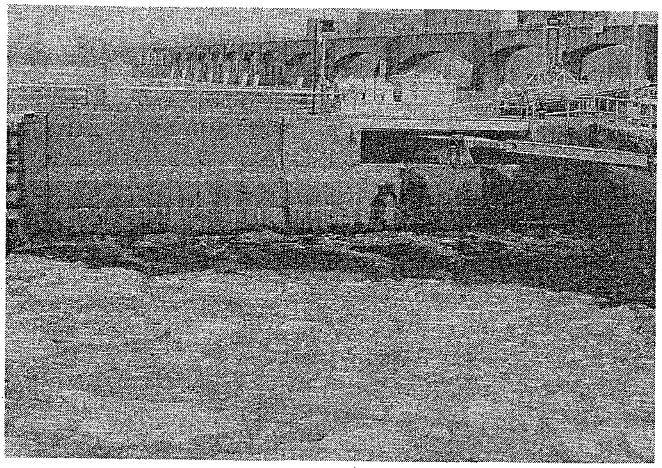


Figure 3. Miter gate recess flusher in operation at Lock and Dam 22 on the Upper Mississippi River

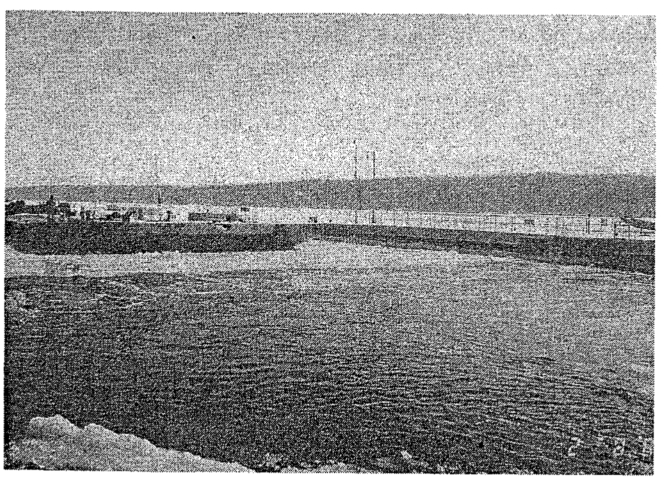


Figure 4. Air screen in operation at Starved Rock Lock and Dam

A deflector air screen is a diffuser line placed at an angle across the upper approach. The purpose of the deflector air screen is to prevent ice from collecting in the upper approach by directing moving ice toward the dam, where it can be passed downstream. The diffuser pipe must be anchored well on the bottom of the river so it will not be moved by towboats and barges passing over it.

In the rehabilitation of locks and dams in the northern states, the installation of a bubbler system is now standard procedure. Installation of part or all of a complete bubbler system should be considered at any lock and dam where ice is a problem. The severity of ice problems depends on their frequency of occurrence and on how many man-hours are required to restore normal operations.

To help in the design of a bubbler system, CRREL has developed a computer program, named BUB300, that determines the correct size of the compressor required and correct sizes of the air supply lines, diffuser lines, and orifices. A copy of this program, written in HP Basic, may be obtained from CRREL. The software is an implementation of the air bubbler design as outlined by Carey (1983). Primary components of an air distribution system are manifold line, supply headers, and the respective diffuser lines, including the orifices. Given the size of the compressor and the size of the primary components, the computer program progressively computes the air volume and pressure drops at the respective piping connections. Interactively, the user can optimize the design by changing the size of the primary components and the size of the compressor. Many Corps Districts have called upon CRREL to design bubbler systems for projects.

The first complete bubbler systems, as shown in Figure 1, were installed at Starved Rock and Peoria Lock and Dams. A deflector air screen was installed at Peoria Lock and Dam but was subsequently removed during a rehabilitation. It is important, but it may also be difficult, to anchor the deflector screen to the river bottom so that it will not be affected by tows passing over it.

High-density polyethylene sheets

Another technique for reducing ice buildup on recess walls is the use of high-density polyethylene (HDPE) sheets mounted over the concrete surfaces (Figure 5). Laboratory tests have shown that ice will grow on these sheets just as it does on steel or concrete. However, it takes 30 times less force to knock ice off HDPE than concrete, and the ice tends to come off cleanly.

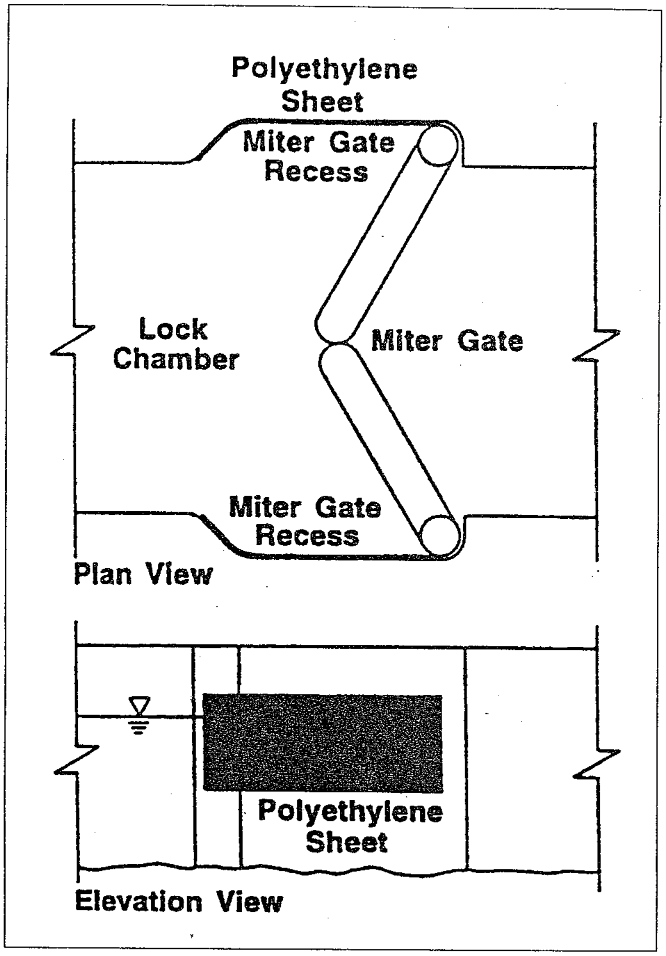


Figure 5. Location of HDPE sheet

HDPE sheets typically have dimensions of 4 ft by 8 ft by 0.5 in. and weigh 80 lb each. They can be attached to the concrete by two or three men working from a boat or barge. First, 13/32-in. mounting holes spaced at 16 in. are drilled into the HDPE sheet and are countersunk for 3/8- by 1/1/2-in. flathead Tapcon screws or the equivalent. The 8-ft side of the HDPE sheet is positioned horizontally with the top 6 in. above the upper pool level. The mounting holes are used as a guide for drilling 3/8-in. holes into the concrete wall. The Tapcon screws are put into the holes with flush mounting heads. Sheets are placed next to each other with no gap.

An HDPE sheet was installed in a miter gate recess at Starved Rock Lock and Dam with results similar to the laboratory tests. HDPE sheets are scheduled to be installed at Dresden Island Lock and Dam on the concrete wall just downstream from the tainter gates, where ice buildup can prevent movement of the gates. A bevelled aluminum plate is needed on the upstream edge to protect the sheet during high water.

The application of any of these techniques to a specific lock and dam requires an evaluation of the severity of the problem and an economic justification for their installation during a major rehabilitation.

For additional information, call Don Haynes at (603) 646-4184.

References

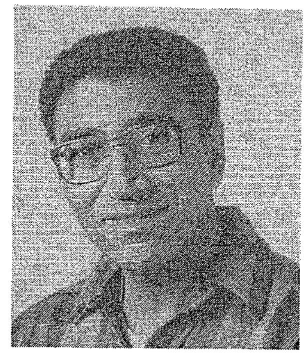
Carey, K. L. (1983). "Melting Ice with Air Bubblers," Cold Regions Technical Digest No. 83-1, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH.

Headquarters, U.S. Department of the Army. (1990). "Winter Navigation on Inland Waterways," EM 1110-8-1 (FR), Office of the Chief of Engineers, Washington, D.C.

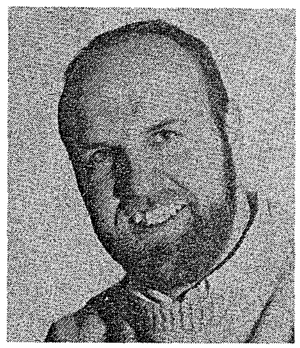
Haynes, F. D., Haehnel, R., and Zabilansky, L. (1993). "Icing Problems at Corps Projects," Technical Report REMR-HY-10, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Donald Haynes *is a mechanical engineer in the Ice Engineering Research Branch, CRREL, Hanover, NH. He has a B.S. degree in mechanical engineering from the University of Arizona and an M.S. degree in mechanical engineering from Michigan Technological University. Haynes has over 20 years of experience in applied research on icing problems and is currently Principal Investigator for the REMR research work unit on icing problems. He is a registered Professional Engineer in the State of New Hampshire.*

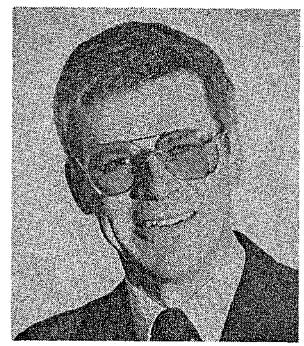
Charles Clark *is an electronics technician in the Ice Engineering Research Branch at CRREL. He holds an AAS degree in electronic engineering technology. He has been an electronics technician for 30 years and has worked at CRREL for the past 12 years. Clark has been a member of the Institute of Electrical and Electronics Engineers (IEEE) since 1963.*



Robert Haehnel *is a research mechanical engineer at CRREL and works in the Ice Engineering Research Branch. He holds a B.S. degree in engineering from Brigham Young University. Haehnel has been involved in the REMR Research Program for 2 years and has been with CRREL for 5 years. He is a member of the American Society for Mechanical Engineers.*



Leonard Zabilansky *is a general engineer at CRREL. In the past 20 years, his research effort has been in the area of ice forces on structures. He is an active member of the American Society of Civil Engineers and the Instrumentation Society of America. Zabilansky is a Registered Professional Engineer in the States of New Hampshire and Connecticut.*



Annual Field Review Group Meeting

The 7th REMR-II Field Review Group Meeting will be held at the Waterways Experiment Station, 19-20 July 1995. Representatives from all Districts and Divisions are encouraged to attend. The meeting will be open to the public as well as to Corps personnel involved in the repair, evaluation, maintenance, and rehabilitation of the Nation's infrastructure. For additional information, contact Lee Byrne, CEWES-SC-A, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-2587 (e-mail byrnee@ex1.army.mil.wes.).

REMR bibliography database

by Roy L. Campbell, Sr.
U.S. Army Engineer Waterways Experiment Station

The REMR Bibliography Database is a source of technical references for persons engaged in the repair, evaluation, maintenance, and rehabilitation activities in the areas of coastal, concrete and steel, electrical and mechanical, environmental impacts, geotechnical, hydraulics, and operations management. The database contains annotated references to REMR technical reports, technical notes, and material data sheets from *The REMR Notebook*, articles from *The REMR Bulletin*, and REMR video reports. (See *The REMR Bulletin*, Vol. 11, No. 3).

Available through the Internet and via modem, the database presently contains records on 540 repair topic products. Additional publications will be added as they become available for distribution.

Internet

Accessing

Internet users can access the database on the World Wide Web with the following URL protocol:

http://www.wes.army.mil/cgi-bin/remr.wais.pl

Browsing

The database browse contains three screens: search-word(s)-entry (Figure 1), items-found (Figure 2), and bibliography. For the search-word-entry screen, use the mouse to activate the search-index box at the bottom of screen before entering search word(s). Press the "ENTER" key after entry has been completed to execute browse.

The items-found screen (Figure 2) lists two lines of data for each item found. The first line includes the path to the bibliography file containing the search word(s), and the second line includes information regarding the file (score, number of lines in the file, and size of the file). To view the contents of the bibliography file, use the mouse to click on the first line of the item. The bibliography screen will then display the contents of the bibliography file. For item displays that are longer than one screen, use the mouse to operate the vertical scroll bar on the right edge of the screen to view information not shown on

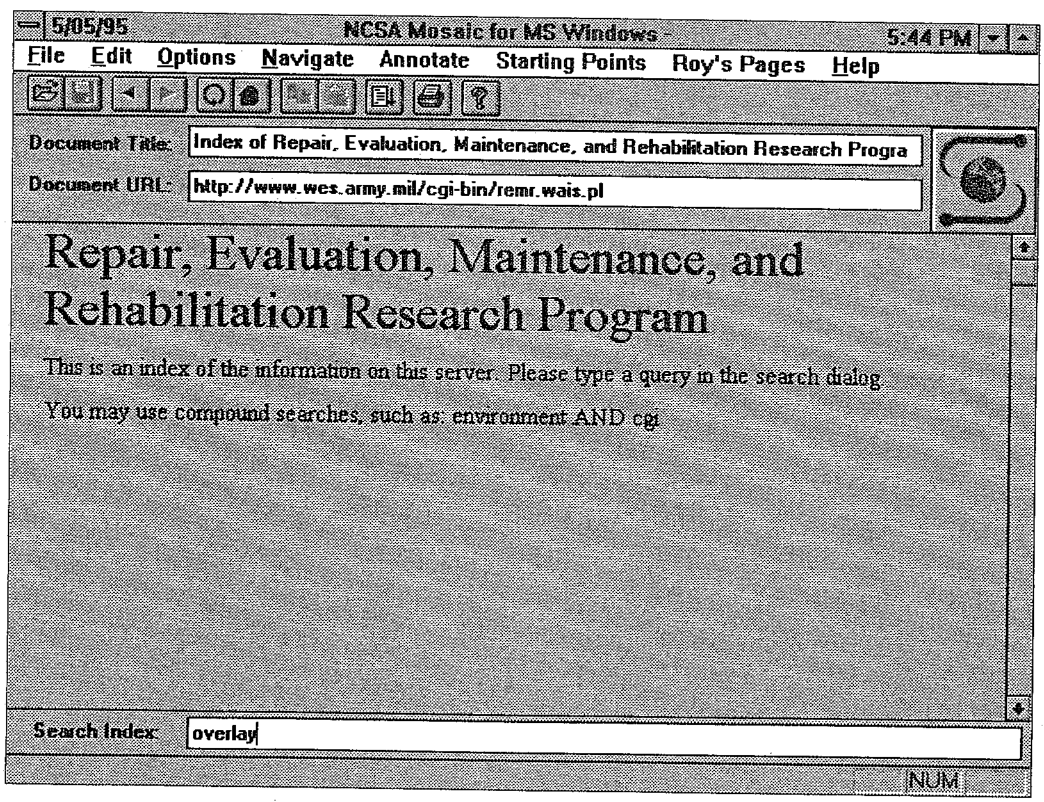


Figure 1. Search-word(s)-entry screen

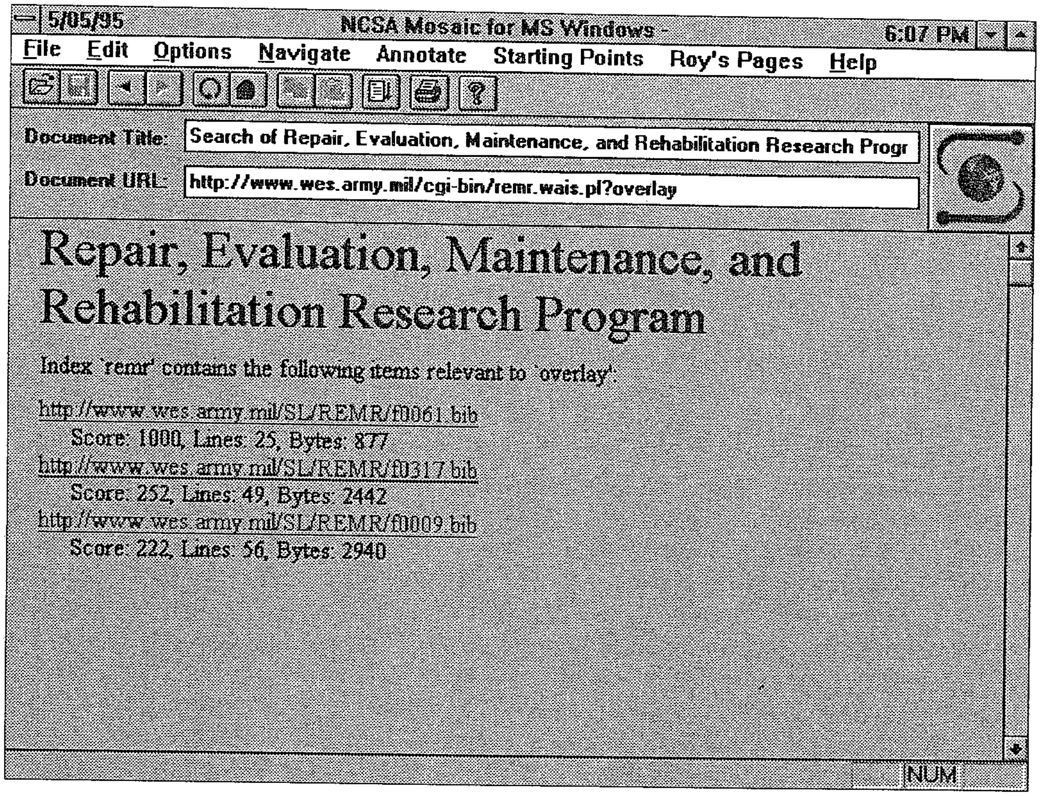


Figure 2. Items-found entry screen

present screen. Left and right arrow button are located at the top of each screen to move between screens.

Search entry

The bibliography database is searched using word(s) entered into the search-index box. Entries must be whole words that are not verbs (am, are, had, ...), prepositions (after, after, for, ...), common adjectives (a, an, the, ...), or common adverbs (also, greatly, too, ...).

The software locates each item containing any one of the search words entered. For example, if the user enters the words "OVERLAY OVERLAYS," all items containing the word "OVERLAY" or "OVERLAYS" are listed on the items-found screen.

Modem

Accessing

The REMR Bibliography Database can be accessed via modem using the following telecommunication parameters:

Baud Rate: up to 9600
Emulation: VT-100
Data Bits: 8
Stop Bits: 1
Phone No.: (601) 634-4223
Parity: None

Browsing

The database is menu driven and includes help windows to facilitate its use. There are no restrictions as to who may access the database, and the only cost to the user is that for the long distance call.

The first menu displayed (Figure 3) is a listing of available on-line databases. Use the down arrow or press the "B" key to highlight the screen line containing "REMR BIBLIOGRAPHY DATABASE," and then press the "ENTER" key to access the database.

The next screen (Figure 4) contains an introduction, search-word(s)-entry box, and hot keys (along the bottom of the screen). Entries into the search-entry box must be whole words. Operators such as "AND," "OR," and "NOT" may be entered to customize searches. (See Search Entry below.)

Once the program has completed its search, a table is displayed that includes the title, author, source, and date for each record found. This table is several screens wide and may be longer than one screen. Use the arrow keys to view portions of the table not shown. To see the description of a highlighted record, press the "ENTER" key. To facilitate use, search words are highlighted in the displayed bibliography. Use the up/down arrow keys to scroll through the description. Press the "ENTER" key to return to the table of records found. To return to the search-entry box screen, hold down the "CTLR" key and press the "Q" key. To quit the program, again hold down the "CTLR" key and press the "Q" key. You should now be back at the first menu. You can use the up/down arrows or press the first letter to highlight an option and then press the "ENTER" key to execute. The "DISCONNECT-QUIT" option terminates the modem connection.

Search entry

Records are searched using word(s) entered into the search-entry box. Entries must be whole words that are not verbs (am, are, had, ...), prepositions (after, after, for, ...), common adjectives (a, an, the, ...), or common adverbs (also, greatly, too, ...).

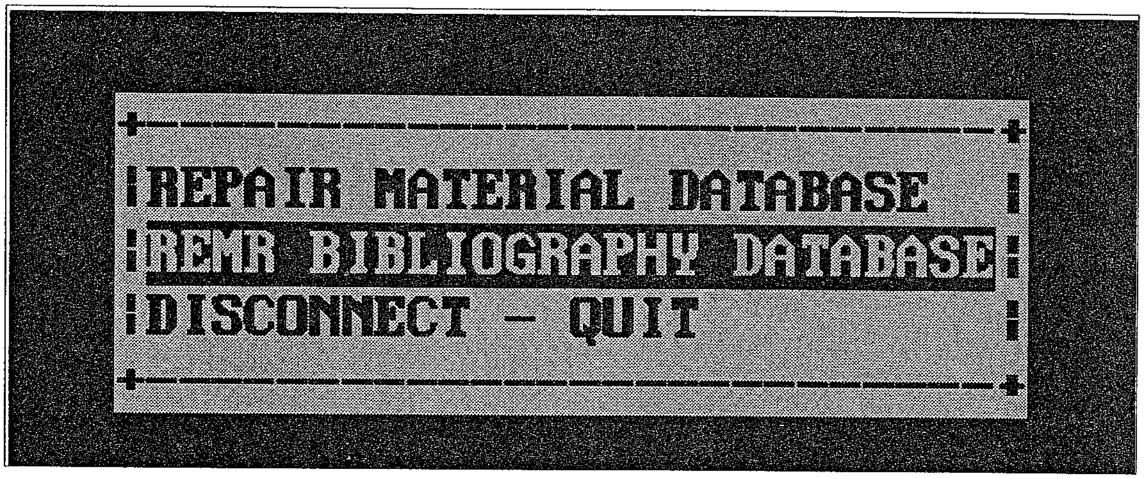


Figure 3. First menu displayed with "REMR Bibliography Database" highlighted

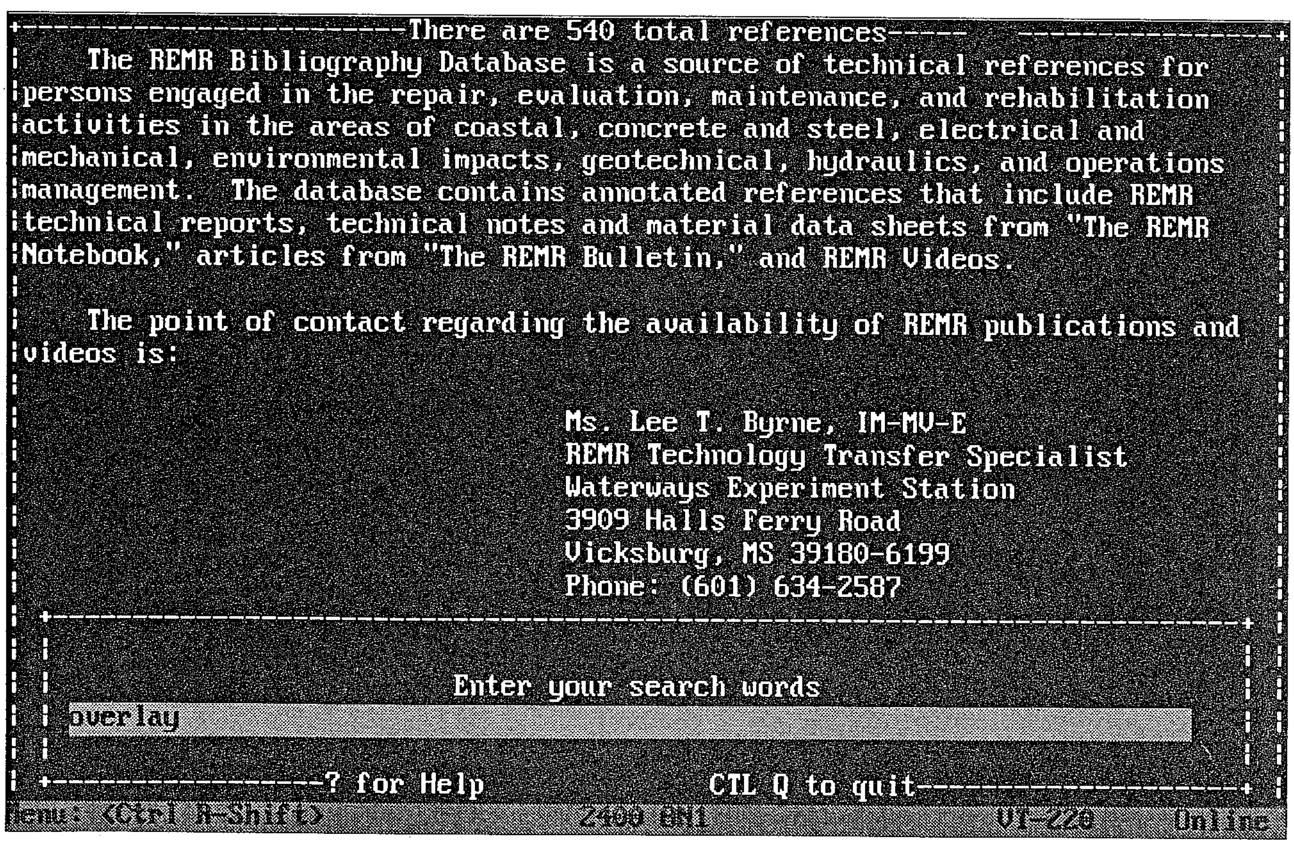


Figure 4. Second screen contains introduction, entry box, and hot keys

Operators

For multiword searches, an operator ("AND", "OR," or "NOT") is used between search words to include or exclude records containing the search word following the operator. The program flags all records containing the first word entered into the search-entry box. All remaining searches are performed only on flagged records, except when an "OR" is used as an operator. When "OR" is used as an operator, all records are again searched. If no operator is used between search words, then the default operator "AND" is used by the program. Descriptions of the operators and records found are as follows:

- AND (Default): Records found will contain search words found on either side of operator.
- OR: Records found will contain at least one of the search words found on either side of operator.
- NOT: Records found will contain the search word(s) in front of the operator and not the search word following the operator.

Example searches

- Example 1: "POLYMER SEALER" or "POLYMER AND SEALER."
  Entry locates all records containing the words "polymer" and "sealer"
- Example 2: "POLYMER SEALER EPOXY" or "POLYMER AND SEALER AND EPOXY"
  Entry locates all records containing the words "polymer," "sealer," and "epoxy"
- Example 3: "POLYMER OR SEALER"
  Entry locates all records containing the word "polymer" or "sealer"
- Example 4: "POLYMER OR SEALER OR EPOXY"
  Entry locates all records containing the word "polymer," "sealer," or "epoxy"
- Example 5: "POLYMER NOT SEALER"
  Entry locates all records containing the word "polymer," but not "sealer"
- Example 6: "POLYMER AND SEALER NOT EPOXY" or "POLYMER SEALER NOT EPOXY"
  Entry locates all records containing the word "polymer" and "sealer" but not the word "epoxy"

Cursor movements

Keystrokes used to move the cursor and highlight records are as follows:

Keystroke(s)	Action
Up arrow	Moves pointer up one line
Down arrow	Moves pointer down one line
Left arrow	Moves pointer to left one column or screen
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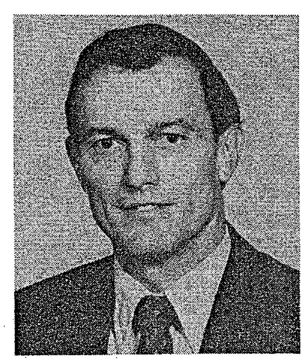

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