X-207-71-10

PREPRINT

NASA TM X- 65421

FINAL TECHNICAL REPORT ON INTENSIVE CARE ALARM INDICATOR SYSTEM

JUNE 22 — AUGUST 28, 1970

JANUARY 1971

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-207-71-10

FINAL TECHNICAL REPORT
ON
INTENSIVE CARE ALARM INDICATOR SYSTEM

J. Lauris Christensen
André L. Hebert

January 1971

David A. Nace
Technical Advisor
Systems Division

PRECEDING PAGE BLANK NOT FILMED

PREFACE

The technical results presented here represent a ten week effort by its authors during the Summer Institute for Biomedical Research sponsored by the Technology Utilization Office at the Goddard Space Flight Center. Their challenge was to apply NASA developed technology toward the solution of this particular problem and to demonstrate its usefulness to other problems in medical diagnostic monitoring instrumentation.

This report has been published and made available for general use so that others in both the technical and medical communities might benefit from the work of these individuals.

Wayne T. Chen
Wayne T. Chen, Coordinator
Summer Institute for Biomedical Research
Technology Utilization Office

INTENSIVE CARE ALARM INDICATOR SYSTEM
TASK V — SCOPE OF WORK

June 26, 1970

A further clarification of the Task IV Scope of Work was prepared. A carbon copy of the memo to Wayne Chen is included below.

June 26, 1970

Wayne Chen
Technology Utilization Branch

Andre L. Hebert
Biomed Summer Institute

Revisions to the Task IV Scope of Work

This week Larry and I have made slight revisions to the Task IV Scope of Work. We are submitting these to you for your approval and for the approval of those involved at George Washington University Department of Clinical Engineering. The revised Scope of Work is as follows:

> Develop a device to be worn by the Intensive Care Unit (ICU) staff (within the immediate area or room) which will indicate when alarms on the monitoring equipment have been activated. The alarm indicator must be noted by the personnel who are wearing the device. Minimum recognition by the patients in the ICU area will be kept in mind.
>
> The input to this device will be a (transmitted) signal (pulse burst) from the monitoring equipment presently available in the ICU. In development of the prototype attempts will be made to use available transmitters and receivers to communicate the signal. The emphasis on the task will be on the development of the alarm device.
>
> Any comments from you or from those at GW will be greatly appreciated.

Andre L. Hebert
Biomed Summer Institute

cc: Mr. Nace
Mr. Ayers
Mr. Landoll
Mr. Lee

CONSTRAINTS ON TASK IV, INTENSIVE CARE
ALARM INDICATOR SYSTEM

June 26, 1970

In a meeting on Wednesday, June 24, 1970 certain constraints were tentatively established on the alarm indicator system. This meeting took place on the first floor of Building 22 at Goddard Space Flight Center, Greenbelt, Maryland. Those in attendance were as follows:

Wayne Chen, NASA, T.U., 982-6242

James Landoll, G.W., 331-6836

David Lee, G.W., 331-6871

Larry Christensen, NASA-G.W., 982-5982

Andre Hebert, NASA-G.W., 982-5982

A listing of the constraints established were as follows:

1. Cost $100
2. Range of signal required; 8 beds maximum
3. Reliability; 95%
4. Number of nurses on duty; 3 during the day, 2 at night
5. Acknowledgement of receipt of alarm by nurse; via reset button at bedside
6. Batteries; rechargable
7. Function of hardware; reception of alarm only*
8. Size; pack of king size cigarettes
9. Fake alarms; not to be considered

---

*Isolated input interface which takes relay closure to ground and stays on until reset by console or at bedside.

Those questions not answered are as follows:

1. The nurses activities and daily routine?
2. Output from the ICU console?
3. Type of existing equipment?
4. Interfacing required?
5. Preferable type of signal?
6. Major problems and gripes with existing equipment?
7. When lessons available on how the system operates, what is the system supposed to do, etc. ?
8. When alarm goes off, how important for patients never to hear or see alarm?
9. How frequently do the alarms go off?
10. Communications and medicine specifications for use in hospitals?

June 26, 1970

PROBLEM OUTLINE

I. Find out generally about the intensive care units and the nursing procedure followed in the ICU to determine the best size and location of the alarm device.

II. Determine which device would provide minimum stress to patients, but would effectively call the nurse.

III. Determine what information would be most helpful to the nurse.

IV. Research various possible alarm systems. Determine the advantages and disadvantages of audible, visual and sensory devices.

Assumption - any alarm system using smell or taste senses will not be effected because of the time involved and because of the limited amount of information that can be received. Also, hearing aid type is out because of nurses' dislike.

V. Proceed in developing various devices.

Yesterday, June 25 Dr. Ayers told me that the alarm device should not restrict the movement of the nurses and that it does not have to be waterproof. The signal emitted by the machine is a simple pulse signal. Suggested either a pin to the lapel or something on the wrist.

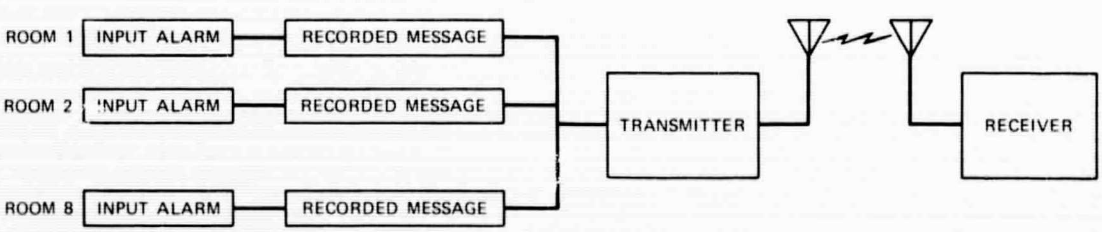
Information most needed by the nurse (D. Lee, June 25) would be the indication that the alarm went off and which patient needs care.

Assumption - It will not be necessary to inform the nurse of pulse EKG information, temperature and heart rate because all of this information is given at the patient's bedside and there are no special procedures followed when just the information above is known (at console) without visiting patient's bedside.

Idea - Use a small radio receiver to accept a vocal command from the console. The vocal command could be given by some tape recording device. The message would be something like "Nurse, patient in room 5 needs care." There are two possible devices which could possibly be used directly: B58 warning device and telephone answering device.

Assumption - It would be less stressful for patient to know or at least think they understand what the signal means. With a vocal message as given above, the patient would know (1) who needs the help (which room) and (2) would not have to believe that it is an emergency, maybe just a patient calling for help of another kind.

Scheme of Device



June 30, 1970 - J. Landoll - not necessary to broadcast which patient needs the assistance.

INFORMATION ON INTENSIVE CARE UNITS

June 26, 1970

The Organization of Intensive Care Units

Report on Prepetory Meeting (Copenhagen, February 3-6, 1969)
Regional Office for Europe - World Health Organization

Number, Location and Optimum Size of CCU

- 8 to 10 beds (one unit) for every 250,000 people
- it is important to ensure that the specific requirements of patients with acute myocardial infarction are respected, particularly with regard to protection by partitions or walls from distressing and dramatic events occurring in adjacent beds
- for economic reasons, optimum size is 6 to 10 beds

Standards of Design and Equipment

- patients should be accommodated in separate sound proof and opaque from each others rooms
- optimum size room is 15 to 20 meters^2
- each window should be provided with a window permitting inspection of the patients from the nursing area
- because it is impossible to directly survey any more than 5 patients there should be a control surveillance area
- displays - ECG's of all patients and slow heart rate warning system for each patient in control area
- following equipment at bedside

  1. Oscilloscope to display ECG
  2. Blood pressure apparatus
  3. Oxygen and vacuum supply
  4. Solid board for external cardiac massage

- following items should be available in the CCU

    1. At least one mobile multi-lead ECG
    2. One or two DC defibrillators
    3. Portable oscilloscopes
    4. Non-implantable pacemaker for transvenous internal pacing (one for every 3 patients)
    5. A mobil X-ray unit
    6. Equipment for sustained artificial respiration
    7. An inter-communication system between the several areas
    8. Adequate laboratory services

Standards for Staffing

- An electronics technical should be available to insure proper functioning of equipment

Participant at this meeting - Dr. S. M. Fox, Chief, Heart Disease and Stroke Control Program, Department of Health, Education and Welfare, Public Health Service, Arlington, Virginia.

A Study of Noise and Its Relationship to Patient Discomfort In a Recovery Room

Nursing Research, pp. 247-250, Minchly, 1968.

- the sense of hearing is of prime importance to postoperative recovery room patients
- neither smell, touch or taste can provide sensory cues for patients reorientation as readily as hearing
- hearing may be distorted by drugs so that unwanted sounds may be subjectively interpreted by the patients as noxious stimuli, adding to their discomfort
- Melazck (Perception of Pain, Sci. Amer. 204 pp. 41-49, February, 1969) has defined pain as the complex experience rather than single sensations produced by specific stimuli. The modifiability of events in the central nervous system and the interpretation placed on it by the individual poses problems in the alleviation of pain

- Gardner (<u>Suppression of Pain by Sound Science</u>, 132, pp. 32-33, July 1, 1960) has shown that noise can be used to reduce sensations of pain.

June 30, 1970

- Gardner's hypothesis - the postoperative patient, already suffering from surgical pain, is made more uncomfortable as the noise over which he has no control in his immediate area increases.
- Sources of noise

  Inamimate - from initially areas at both ends of rooms, e.g., water taps running, telephone ring, clatter of utensils

  Animate - talking
- Sound ranges - 40-50 decibels (low), 50-60 decibels (medium), 60-70 decibels (high). Each increase of ten decibels in the intensity of sound stimuli doubles the subjective sensation of loudness.
- The experimenter found sounds of 60-70 decibels produced a decidedly noisy environment
- noted that more drugs are requested as the noise level increases
- a patient is sickened by the sound of vomiting; pained by the cries of others and most disturbed by the laughter of working personnel
- lack of response by the patient to the sound of the telephone or a patient's snoring may indicate that such sounds do not connote human distress or that they do not evoke the same response that would occur if the telephone were the patient's own telephone.

Environment of ICU - Nursing Forum 6:262-272

- they may not have seen what was happening, but they heard a great deal and imagined much more
- noticed a general sense of urgency in the ICU
- people talked about them without including them in the conversation
- patients receive an over stimulation and emotional deprivation
- use could be made by sound devices by which patients can be heard by the staff, but do not themselves hear sound from other areas

July 1, 1970

Hackett, T. P. et al., The Coronary Care Unit: An Appraisal of Its Physchological Hazards, New England Journal of Medicine 1365-1370, December 19, 1968.

Modern Hospital, Special Section on Intensive Patient Care, Vol. 100, Number 1, January, 1963.

- Pacemakers - to start up the stopped heart
- Electronic defibrillator - to convert a fibrillating (random beating) heart to a stopped heart so that the pacemaker may be used
- These methods must be employed within a few minutes of when the unpredictable hazard strikes the heart

Pilot Oxygen Mask with Tactile Transducer Providing Warning Signals From Wireless Communication A65-11394

Some Neglected Possibilities of Communication. Science 131:1583-1588 May 27, 1960 Frank Bildard (Xerox copy)

- Chest region - amplitude of 50 and 400 microns
  duration 0.1 to 2.0 seconds
  frequency 70 cps

Potential Answers to Communications Problems. Glenn R. Hawkes, Ph.D Aerospace Medicine, Vol. 33, No. 6, June 1962, p 657

- In situations where subjects respond to the presence of infrequently presented electrical cutaneous, mechanical or auditory signals of weak intensity levels, response latency and signal detection relative to that with auditory stimuli were poorer for vibratory systems
- When moderate stimulation was employed, the efficiency of cutaneous signal detection relative to auditory was well maintained

July 6, 1970

TELEPHONE CORRESPONDENCE AND INFORMATION COLLECTION

Listed on the following page, in no particular order, are some of the more important telephone calls placed by Andre L. Hebert during the period from

June 25, 1970 to July 2, 1970 for the intensive care alarm indicator system. Names of firms and individuals, together with telephone numbers and cities, if available, are included for later reference. More elaboration and/or content of the call(s) will be included following the list as deemed necessary.

1. NASA Tech. Brief 68-10365
   T. U. (Technology Utilization)
   Ames Research Center
   Moffett Field, California 94035
   Mr. Emerson
   415-961-2631
   Sending additional information 6/26/70 and has minitransmitter

2. John Dirneoff
   Instrumentation Division
   Ames Research Center
   Moffett Field, California 94035
   415-961-2186

3. Jack Pope
   Ames Research Center
   Moffett Field, California 94035
   415-961-2951

4. Alexian Brothers Hospital
   225 North Jackson Avenue
   East San Jose, California 95216
   408-259-5000
   John Roden, Director of Engineering at Alexian
   Details of how use Motorola
   Pocket Beepers, $200-$300/unit
   3 years old

5. Motorola Hospital Division
   301-647-8900
   Benedict Allison
   Set up meeting at 9:30 a.m., Wednesday, July 1, 1970 to discuss the Automatic Mark II Motorola System. Features Allison mentioned on phone:

   (a) can split ICU for nurse responsibility

   (b) can set priorities and override

   (c) Size 11/16" x 2-1/2" x 4-7/16"

(d) 6-1/2 oz. Mercury battery

(e) Worn in pocket or on belt

(f) $202/payer + $5 installation

6. NASA Tech. Brief 69-10725
   Pocket-sized tone-modulated
   FM Transistor and patrol car receiver
   Transmitter-tape recorder-player combination
   T.V. "Squer"
   NASA Pasadena Office
   213-354-2240

7. NASA Tech. Brief 67-10369
   Alarm Monitoring
   Wheeler, Manned Spacecraft Center
   T. U. Houston, Texas 77058
   713-483-3809

8. NASA Tech. Brief 68-10131
   Patient Monitoring System
   David Winslow
   T. W., Marshall Space Flight Center
   Huntsville, Alabama 35812
   205-453-2224

9. Joseph L. Seminara
   Bioastronautics Organization
   Lockheed Missiles and Space Co.
   Sunnyvale, California
   408-742-4321
   Re to: Warning - Systems Design, in Machine Design, Vol 37, September 30, 1965, pp 106-116

10. Bell Labs
    Murray Hill, New Jersey
    201-582-3000
    Jim Kaiser Ext. 2058

11. John Hopkins University
    301-955-3131
    Morse Goldstein (in Jerusalem 7/1/70 - 7/1/71)
    Spoke with Andrews (physics graduate and in biomedical engineering field 6 years)

(a) Pocket on nurse 3/4 size of man's pocket

(b) Bothered by audio sound

(c) If worn in upper pocket can use muscle frequency and not audio and not visual

(d) Known receivers belt size and for a larger range (1 building, etc.)

12. Amperex
North American Philips Co.
Slatersville, Rhode Island 02876
Providence Pike
401-762-9000
and Walter Bosse - Integrated Circuits, 401-737-3200
and Roger White - Speakers, 516-234-7000

13. Arlington Electronics
Amperex (a) TAA 300 and (b) TAD 100 in stock at (a) $3.37 and (b) $3.99

14. Telex Lapel Paging Speaker LS99
1-1/2" x 1-3/4" x 5/8," 0.78 oz, $12.20 each
David H. Brothers
Brothers and Conneen Associates
6302 Lincoln Avenue
Baltimore, Maryland 21209
301-764-7189

15. Dr. Charles Vunss
Louisiana State University
Electrical Engineering Department
504-388-5241

(a) Integrated circuits and small
video amplifiers
broad band FM and use
tuner and amplifier
watch which would beat diaphram on back

(b) Buzzer take a lot of current

(c) Medium shock little current and easy on batteries
Tingling sensation if electrodes close to each other

(d) Super regenerative detector, coils wound, transistor (chip type) and vibrator, shocking and battery

(e) watch out for FCC regulations

16. Jack Pope
    415-961-2925
    To develop receiver for specific job is very expensive ($500)
    and black magic
    Ames Research Center
    Moffett Field, California

17. Dr. Irene Hsu
    G. W. Hospital, Head of Intensive Care
    331-6170 or 331-6646

July 8, 1970

Meetings July 1, 1970 and July 7, 1970 About Motorola Pocket Beepers

On Wednesday, July 1, 1970, Benedict Allison from Motorola Hospital Communications visited Goddard. General information was presented by Allison to Hebert, Christensen and Landoll. The apparatus thought to be applicable by Allison for the given problem was the Automatic Mark II Automatic Nurse Call System.

Further information was presented to Hebert and Christensen on Tuesday, July 7, 1970, on the Automatic Mark II System. At this time it was decided that the above system was not applicable to this problem. Allison then recommended the installation of a Motorola Bay Station ($2,500) with "pocket beepers" to be able to be used in the event the Motorola System came under more serious consideration.

Methods of Signaling

The types of signals considered for indication of the alarm to the nurse are generally as follows:

1. Music

2. Small lights

3. Broadcasting names of nurse and/or verbal message

4. Beeps, buzzes

5. Sensory touch stimulation

Two experimental setups have been tried in the lab, the first with Nase and Hebert and the second with Nase, Christensen and Hebert.

The first was to attach a 1-1/2" diameter speaker to the wave generator. Some questions were still unanswered in that with this speaker both the nurse and the patients could hear the alarm from the 1-1/2" speaker.

The second one, performed today, was using a 50ft, 4-wire inductive loop. The input to the loop was by the wave generator and a 10-watt amplifier. A Radioear Model 990 Microphone-Telephone (Inductive loop systems receiver as the telephone end). Hearing aid was used as a receiver. Satisfactory results were obtained to substantiate the promise that, to a certain extent, the nurse only could be warned without, or with a minimum, recognition by the patients in the intensive care unit.

Further investigations will probably be directed to try to reduce the cost of the $300 Model 990 hearing aid and incorporated this new receiver into an inductive loop system.

Meeting on Inductive Loop Systems at the Kendall School
On the Gallaudet College Campus, July 6, 1970

On July 6, 1970 Christensen and Hebert visited Dr. Behrens and Art Keiser at Gallaudet College. Demonstrations were performed on many of their hearing and signaling devices including their inductive loop systems in the classrooms and on bone conductor receivers.

A Radioear Model 830 hearing aid with both telephone and microphone capabilities was loaned to Hebert and Christensen.

Art Keiser gave further explanation on inductive loop systems and their installation at Kendall School.

Art Keiser - 386-5009
Dr. Behrens - 386-5571
Kendall School - 386-5009

Also, at Gallaudet College Speech and Hearing Center can contact Bill Mullen or Dr. Cox at 386-6531. Supposedly, (from Dan Drake at Telex Hearing Center - RE 7-1977, 601 13th Street, N.W., Washington, D.C.) another inductive loop system and knowledge thereof can be seen and discussed by contacting Mullen and/or Cox.

Radioear Hearing Aid Inductive Loop Receiver Meeting, July 7, 1970

Mr. Fred Steward at Radioear, 916 19th Street, N. W., Washington, D. C., 541-4557 (Home phone 654-6908) on July 7, 1970 gave Christensen and Hebert a demonstration on bone conductor receivers and miniature hearing aids.

A Model 990 Radioear Hearing Aid-Telephone inductor coil receiver was loaned to Hebert for 10 days. This was the receiver used in the second experiment on page 14.

The inductive loop system used was a modification of the one included in a report entitled "Recommendations for Radioear Phonomaster Installation in the Translux Theater, 14th and H Streets, N. W., Washington, D. C." for McKee and McCormick, 711 14th Street, N. W., Washington, D. C., by Radioear Corporation, 306 Beverly Road, Pittsburgh, Pennsylavnia, dated March 3, 1952.

The above report and a report by Charles Diaz, E. E., 121 Oak Street, S. W., Vienna, Virginia, entitled "General Description of Operation of an Induct-A-Loop in conjunction with a 'T' Pad," were both given to Hebert and Christensen by Stewart.

July 8, 1970

Information on miniature batteries was requested on July 6, 1970 from Power Information Center, 3401 Market, Philadelphia, Penn., 215-EV2-8683, Mr. John Peirson (also can contact Col. Paul Balas).

Additional information was requested from Mr. Tirk of Gould-National Batteries, Inc., 2630 University Avenue, S. E., Minneapolis, Minnesota, about Ni-Cad Button size batteries. Also, Mr. Bill Kuhl, 654-6712, Silver Springs, can be contacted locally about these batteries. A catalog is supposed to be on the way.

July 9, 1970

Tactile Device Literature Search

Some Defected Possibilities of Communication. Frank Gildard, Science 131:1583-1588, May 27, 1960.

- signal spplied to chest region can be felt at following conditions:

Amplitude - 50 to 400 microns

duration - 0.1 to 2.0 secs

frequency - 70 cps

- this is for a vibrator system

Oxygen Mask with Tactile Communication Devices, F. Zawestowski, Aerospace Medicine, November, 1964, p. 1040.

- the tactile transducer is composed of five components:

    1. vibration generator
    2. head
    3. transmitting
    4. casing
    5. connective cable

Potential Answers to Communications Problems, Glen Hawkes, p. 657, June, 1962, Vol. 33, No. 6, Aerospace Medicine

- when moderate stimulation was employed . . . efficiency of cutaneous signal detection relative to that with auditory stimuli was well maintained.

Information on piezoelectric material as possible vibrator was received from:

> Piezoelectric Division Clevite Corporation, Bedford, Ohio
> Telephone: 216-232-8699

July 9, 1970

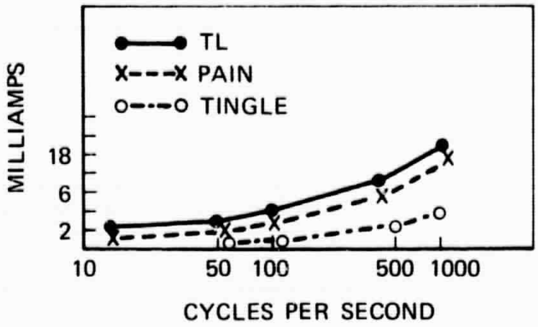
From the Clevite Corporation we got material concerning their Bimorphs as motor transducers. It would appear possible to obtain the necessary amplitudes for cutaneous stimulation from these Biomorphs.

The Sensory Range of Electrical Stimulation of the Skin

G. W. Hawkes (U. S. Army Research Laboratory). American Journal of Psychology, Vol. 73 #3, September, 1960.

- Application of alternating current to the skin under appropriate conditions will elicit sensations of pain, pressure, tingle, warmth, cold. Of these only pain and tingle can be routinely elicited.

- RL - absolute threshold of tingle and pain
  TL - tolerance limit of tingle and pain



- Qualitative reports

  tingle - weak sensation localized in a small area

  pain - localized sensation similar to a needle penetration

  TL - burning and muscle contractions

- It should be noted that the energy ranges determined by such a procedure are still considerably less than comparable ranges for vision, audition, or mechanical vibration of the skin.

Modifications to Radioear Model 1000 as Per Telephone Conversation with Lybarger

July 9, 1970

On July 9, 1970, Hebert called S. F. Lybarger at Radioear headquarters, 412-941-9000, 375 Valley Brook Road, Cannonsberg, Pennsylvania 15317. Lybarger was receptive to the idea of using the inductive loop features of the Radioear hearing aids as a small receiver for the I.C.U. nurse alarm system.

He recommended the use of a Model 1000 Radioear hearing aid rather than the more powerful Model 990 on loan from Fred Stewart, Radioear, Washington, D. C. He intends to modify the existing Model 1000 by removing the microphone and adding an inductive loop.

July 10, 1970

On July 10, 1970, Hebert placed a follow-up call to Lybarger to indicate the possible interest in his modified Model 1000 unit. Lybarger was ill but Hebert left a message indicating the interest he had found during his and Christensen's morning visits, described on the following pages.

Comments from Meeting at Veterans Administration Hospital
Washington, D.C., with Miss M. Geraghty, R.N., et al., July 10, 1970

On July 10, 1970, Hebert and Christensen visited Miss M. Geraghty, R.N., at the Veterans Administration Hospital Medical Intensive Care Unit in Washington, D.C., 483-6666, 4-B East

General comments from the meeting this morning are as follows:

1. When in the ICU, Bed #4 alarm on console went off twice in less than 5 minutes;

2. Prefer using existing buzzer tone as the transmitted signal;

3. Not want voice communication - sometimes it becomes garbled;

4. Very important to have receiver worn by nurse, especially at night with skeleton shifts;

5. Would be advantageous to cut down existing buzzer blaring through the whole ICU;

6. Like to have nurse reset alarm only when go to bedside;

7. Prefers receiver - speaker in pin form rather than behind the ear;

8. Not really needed to broadcast room (or bed) number, but only that there is an alarm;

9. Like to add Code Blue alarms to ICU warning alarms as a later feature;

10. No interference picked up with Model 990 Radioear when walked in V.A. Hospital, ICU.

11. Alarm phone should be obnoxious enough to be sure she hurries to turn it off and take care of patient.

Comments from Meeting at Sibley Hospital, Washington, D.C.
with Miss Bright, R.N., July 10, 1970

On July 10, 1970 Hebert and Christensen visited Miss Bright, EM 3-9600, ext. 558, at Sibley Hospital in Washington, D.C.

General comments from the meeting this morning are as follows:

1. Cannot hear alarm when in patient's room with door closed (i.e., while bathing, using bed pan, etc.) - small receiver worn by nurse badly needed;

2. Not needed to tell which room - can tell room number when in corridor from number of clicks on EKG machine;

3. Pin-on type receiver preferred;

4. No interference picked up when using Model 990 Radioear in ICU at Sibley;

5. Buzzer OK - Music would be nice, voice messages not necessary;

6. Buzzer not alarming to patients due to large number of false alarms.

Pro's and Con's of Inductive Loop System

Why Inductive Loop?

1. very small chance of outside disturbances

2. no operator required

3. used by Motorola in some of their pocket beeper systems

4. low cost - 4 lead copper wire and simple amplifier

5. inductive loop is good for small areas such as intensive care units

6. used at Kendall School

7. no permit from FCC required

Why Audible Signal?

1. not necessary to completely isolate patient from signal--just reduce intensity of signal

2. attracts attention of the nurse no matter what position her head is in—as opposed to lights

3. most common form of alarm

4. much work has been done in this area—as opposed to tactile

5. request of nurses at Sibley and V.A. Hospitals

6. easily interfaced with existing equipment which uses same type of buzzer and/or clicks

Why Hearing Aid Type of Receiver?

1. very small

2. very reliable

3. developed to work on induction coil type systems

4. can be made relatively cheap, although actual hearing aids are not

Why Not Such A System?

1. possible notification of patients

2. adds another buzz and/or beep in intensive care unit

July 13, 1970

Telephone Call - S. F. Lybarger

During a telephone call with Hebert this morning, Lybarger recommended not to have the output in the 500 hertz range, but rather in the 1500-4000 hertz range.

In addition, if the nurses object to wearing the small receiver behind the ear, Lybarger suggests either

1. Hair barrette with receiver cemented on, or

2. Small pin on plate with receiver cemented on.

When and if his receiver modifications are successful, more information will be available.

When Hebert spoke with Lybarger this afternoon, Lybarger had successfully packaged an inductive loop into a Model 1000 hearing aid casing. Final weight of this modified Model 1000 with battery, was 0.2 oz. Checks for feedback still had to be completed. Packaging was probably going to be in the form of a pin and/or behind the ear.

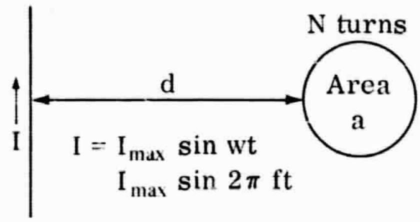
July 17, 1970

Must determine whether the inductive loop will interfere with other equipment found in the intensive care unit.

Preliminary List of Equipment Found in Intensive Care Unit

- EKG
- Pacemakers
- Defibrillators
- Mobile x-ray
- Artificial respirator
- Intercom-telephone
- Lab equipment

Calculation of Magnetic Field Generated (D. Nace)



For an infinitely long conductor

$$B = \frac{\mu_{air}\ I}{2\pi\ d}$$

$$\epsilon = -N \frac{d\phi}{dt}$$

$$\phi = AB = \frac{a\mu\, I_{max} \sin wt}{2\pi d}$$

$$\epsilon = -N \frac{d}{dt}\left(\frac{a\mu}{2\pi\ d}\ I_{max} \sin wt\right)$$

$$= -N \frac{a\mu\, I_{max}}{2\pi d}\ w \cos wt$$

$$\epsilon_{rms} = -\frac{N\, a\mu w}{2\pi d}\ I_{rms}$$

estimate

$d = 10$ meters

$a = 5 \times 10^{-4}\ m^2$

$I = 2.75$ amps

$$\epsilon_{rms} = \frac{4\pi \times 10^{-7}\ (5.0 \times 10^{-4})\ 10^3\ (2.75)}{10}$$

$$\epsilon_{rms} = 0.17 \times 10^{-6}\ \frac{\text{volts}}{\text{turn}}$$

$$= 0.17\ \frac{\text{microvolts}}{\text{turn}}$$

$$\boxed{\epsilon_{rms} = -\frac{N\, a\mu\, f}{d}\ I_{rms}}$$

Today Hebert spoke with Jim O'Brien, Applications Engineer and Marketing with American Optical Company, the main office in Bedford, Massachusetts. His telephone number was 8-0-617-275-0500, ext. 336. He seemed enthusiastic and referred Hebert to:

Mr. Phil Brooks, Research Division, Farmington, Mass.
Telephone: 8-0-617-527-2785
879-1880

Brooks felt that the device using the inductive loop would not interfere with any of the existing equipment for the following reasons: most equipment is in a metal cabinet, temp and thermometer run direct current beyond the frequency of EKG 100 cycles, pacemakers - no, telemetry is in RF region.

July 20, 1970

Hebert came in touch with American Optical Co. local representative Dick Williams, telephone 946-5012 (answering service) or 273-5341 (home). Williams suggests getting together on July 23, 1970.

Some articles that were read concerning the equipment in an ICU:

1. G. Church: Low Cost Coronary Care Unit Equipment, Journal of the American Medical Association 206:2523-2524, 1968.

Equipment provided by Sanborn Division of Hewlett Packard Co.

- oscilloscope
- heart rate meter with light alarm
- synchronized direct current defibrillator
- an internal-external pacemaker
- electrocardiograph machine
- battery operated fixed rate pacemaker, a catheter and a few items for transvenous pacing
- non-synchronized defibrillator

2. Good reference is needed - D. G. Julian. Disturbances of Rate Rhythm and Conduction in Acute Myocardial Infarction. American Journal of Medicine 37:915-927, 1964

3. Medical Electronic Equipment, 1969-1970, ed. by G. W. A. Dummel and J. M. Robertson, Pergamon Electronics Data Sines

Cardiac Arrest Systems

Beam-Matic Hospital Supply, Inc.	Model 5000
Sorensen Division	Cardiac Arrest
25-11 49th Street	System
Long Island City, New York 11103	273-7010

Pacemakers

American Optical Instrument Company	Model 10950
Cosby Drive	
Bedford, Massachusetts 01730	
Electrodyne	
Division of Becton, Dickenson and Company	
15 Southwest Park	portable transistor
Westwood, Massachusetts 02090	Pacemaker Model TR-3
General Electric Co.	Implantable Cardiac
X-Ray Department	Pacemaker Generators
4855 Electric Avenue	Interim Cardiac Pacemaker
8-0-414-383-3211	Dual or single pass electrodes for abdominal and myocardial implant

July 20, 1970

Defibrillators

American Optical

Medical Division - Cat No. 10645

The Birtcher Corporation - Model 415 Depolarizer

Medical International Division

4731 Valley Boulevard

Los Angeles, California 90032

8-0-213-222-9101

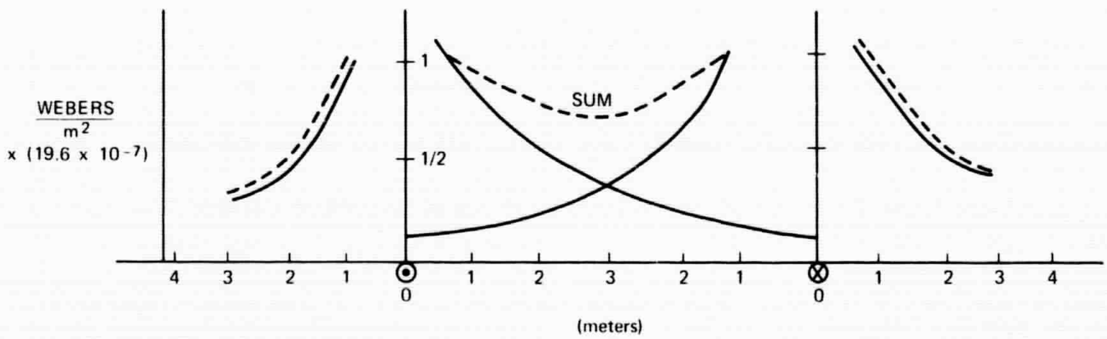
July 21, 1970

Graph of Distribution of Magnetic Field (two parallel wires)

We know that $B = N \frac{\mu_{air} I}{2\pi d}$ for an infinately long wire

Assuming an amplifier of 60 watts is used and the coil has a resistance of 10 ohms, then B becomes $B = N \frac{4\pi \times 10^{-7} (2.45)}{2\pi d} = \left(\frac{4}{d}\right) 4.9 \times 10^{-7} \frac{\text{Webers}}{m^2}$

Assume hall corridor is 3 meters across $\boxed{B = 1.9 \times 10^{-6} \left(\frac{1}{d}\right) \frac{\text{Webers}}{m^2}}$



July 21, 1970

More telephone calls.

Referred by Beam-Matic to Cardiac Electronics, Mr. George Tatoian, 8-0-716-759-6167
Load rejection system. Operated on 100 cps bandwidth

Dr. Peter L. Frommer, Myocardial Infarction Branch, National Heart Institute, Bethesda, Maryland 496-1081

July 23, 1970

Christensen called Lybarger today concerning the receiver end of the alarm system. Mr. Lybarger related that the model 100 radioear has an output of 121 db when an ear model is used. The model 990 can be made to release more power than the model 100 because (1) it has a larger gain and (2) the space occupied by the microphone can be also filled with a larger inductance coil.

Concerning the inductance coil, Lybarger said that best results would be obtained if the coil completely surrounded the intensive care unit along the outside walls. The magnetic field drops very quickly when one is outside of the loop.

July 24, 1970

Called Dr. P. L. Frommer to find out if he knows of any electrical standards that have been developed for Intensive Care Units. He said that more have been developed as of now. Dr. Frommer suggested florescent lights and portable x-ray equipment as possible interference sources.

Idea: Add a mechanical horn to audioear.

PRECEDING PAGE BLANK NOT FILMED

INTENSIVE CARE UNIT NURSE ALERTING SYSTEM

A Report for

GEORGE WASHINGTON UNIVERSITY
DEPARTMENT OF CLINICAL ENGINEERING
AND
NASA GODDARD SPACE FLIGHT CENTER
SUMMER BIOMEDICAL TECHNOLOGY UTILIZATION INSTITUTE

by
J. Lauris Christensen
and
Andre L. Hebert

July 14, 1970

INTENSIVE CARE UNIT NURSE ALERTING SYSTEM

ABSTRACT

In the Intensive Care Unit (ICU) of 3 hospitals in the Washington, D.C. area (George Washington,[1] Veterans Administration,[2] and Sibley[3]), it has been noted that improvements could be made in the nurse alerting system used with the physiological monitoring equipment. A possible solution using an inductive loop system with an audible signal is presented below.

DEFINITION OF ICU

Generally, a medical ICU is an area of the hospital used for those patients requiring more attention than is usually available in the normal hospital environment, hence the name of Intensive Care Unit. This condition of the patient might be necessitated by many factors, such as a severe heart condition.

BACKGROUND

Physiological monitoring units, such as an electrocardiographic (EKG) unit keep a constant surveillance on the patient. If and when the HIGH-LOW limits set by the physican are exceeded on the existing equipment, a buzzer alarm is sounded from and together with a light being activated on the centrally-located console of the ICU equipment. As an example, this alarm was sounded twice in less than 5 minutes when observed during the actual use.[1,2]

Whether these are actual or erroneous alarms from the existing monitoring equipment, still they are broadcast up and down the corridors and into any of the patients' rooms with the doors open.

SCOPE OF WORK

Therefore, it was decided to "Develop a device to be worn by the staff responsible for care (usually within the immediate area of room) which will indicate when alarms on monitoring equipment have been activated."[4]

INDUCTIVE LOOP SYSTEM WITH AUDIBLE SIGNAL

Several alternatives were investigated as solutions for this problem, but an inductive loop system, using an audible signal was selected. Reasons for this selection include the following:

1. low cost 4-lead copper wire and commercially available amplifier and receiver;
2. no permit from FCC required;
3. small chance of outside disturbances;
4. low ambient noise level;
5. no operator required; and
6. inductive loop system is good for small areas such as classrooms[5] and Intensive Care Units.[6]

A sketch of the prototype system as could be used in an ICU is presented in Figures 1 and 2. The floor plan, type of interface, amplifier output, and packaging of the receiver are some of the variables which must be established prior to final installation at each location.

Three major types of signals, (a) audible, (b) visual, and (c) tactile, were investigated for use in this alerting system. An audible signal was selected for many reasons including those listed below:

1. attracts attention of the nurse no matter what the position of her head;
2. a common and usually recognized form of alerting signal;
3. easily interfaced with existing equipment which uses some type of buzzer and/or clicks; and
4. request of nurses in ICU.[2,3]

PROTOTYPE EQUIPMENT

Loop System

The loop system used in the prototype is a modification of the loop system described by Lybarger.[7] A diagram of the prototype loop system, as applied to an ICU, is indicated in Figures 1 and 2.

The output of the Hewlett Packard Model 3310A Function Generator was fed into a Harman Kardon Model C-100 amplifier. As a safety feature, a Hewlett Packard Model 3400A RMS Voltmeter was used to insure a low (7 volts) voltage level.

From the amplifier the signal was carried to the 5-140 strip and then through the loop. The loop wire, 4 strands of 50 foot insulated copper wire connected in series, was wrapped in masking tape for ease in handling and then taped onto the walls in the lab.

The system while in operation was tested with the Model 990 Radioear receiver[8] described below.

Receiver

The small (1.79 inches by 0.63 inches by 0.45 inches, 0.3 ounce) Model 990 Radioear receiver, which was on loan,[8] but which can be modified for use exclusively with an inductive loop system, was selected for the following reasons:

1. small size;
2. readily available;
3. reliable;
4. repair service when needed; and
5. ease in change of batteries.

During the hospital investigations in the actual ICU's,[2,3] the Model 990 was operated to check the interference from the existing hospital equipment. The results were negative.

CONCLUSION

In conclusion, it is advised to use an inductive loop system, such as the one described above, for a Medical Intensive Care Unit Nurse Alerting System.

In the prototype, attempts to use existing equipment were successful. At the same time, the equipment was relatively inexpensive and, in the case of the receiver, already in a miniaturized form.

FOOTNOTES

1. NASA-GW Summer Biomedical Technology Utilization Institute Visit, June 23, 1970, Washington, D.C.

2. Veterans Administration Hospital Investigation and Visit by Hebert and Christensen, July 10, 1970, Washington D.C.

3. Sibley Hospital Investigation and Visit by Hebert and Christensen, July 10, 1970, Washington, D.C.

4. NASA-GW Summer Biomedical Technology Utilization Institute Problem Outlines, June 22, 1970.

5. Kendall School of Gallaudet College Speech and Hearing Center Visit by Hebert and Christensen, July 6, 1970, Washington, D.C.

6. Motorola Hospital Communications Division Visit to Goddard, July 1, 1970.

7. Lybarger, S.F., "Recommendations for Radioear Phonemaster Installation in the Translux Theatre, 14th and H Streets, N.W., Washington, D.C.," March 3, 1952.

8. Model 990 Radioear receiver, V9069, 2F2184, and Radioear Engineering Bulletin Model 990, EB-22 7/1/MCL, Radioear Corporation, 375 Valley Brook Road, Canonsburg, Pa. 15317.

PRECEDING PAGE BLANK NOT FILMED

Task IV
INTENSIVE CARE UNIT NURSE ALARM SYSTEM

COMMENTS

Methodology

Methodology for this task was extremely good. One of the students was heavily oriented in system analysis; therefore, he developed a very detailed plan to approaching the problem. Considerable time was spent in problem definition. Preliminary data were gathered from various sources, both medical and non-medical, such as intensive care units in three hospitals in the Washington, D.C. area; various vendors of telemetry equipment; nurse call systems; radio links and other related equipments. Several alternative solutions were investigated, such as several methods of interfacing the alarm signals to the personnel responsible for patient care. This could be a buzzer, a light, tactile device or other. Good organization of material and thought are evident throughout and a fairly formal report was included in the laboratory notebook. The report was well ordered, included a table of contents and contained basic elements of an acceptable engineering technical report, listing scope of work, methodology and conclusions.

Results

The work revealed a commercially available nurse call system which met most of the requirements, but was very expensive to implement. Further work included a design of an inexpensive inductive loop transmitter and modified hearing aid. This system was breadboarded to the extent that actual tones were transmitted and received by an "ear" receiver. The laboratory notebook reflects an in depth search into many of the aspects of this task. The personal contact with intensive care unit areas was invaluable to the students and contributed significantly to the task.

Conclusion

The students' conclusion of this task was to recommend the use of an inductive loop system. The prototype that was constructed indicated that such a system is relatively inexpensive and in the case of the receiver in miniaturized form.

Future Application/Expansion

Mr. Christensen extended his work period for two weeks and analyzed the requirements of the Multitest Facility at the George Washington University. A plan was worked out for placement of the inductive loop in the Facility. Equipment was specified as to power requirements and cost. A decision can now be made to use the Multitest Facility as a prototype testing environment before implementation of the more stressful area such as an intensive care unit.