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LORAN-C FLIGHT DATA BASE

A large file of Loran-C data to be used in receiver design and testing is documented.

by

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I. INTRODUCTION

Loran-C time-difference data were collected using the Ohio University DC-3 Flying Laboratory on January 9, 1979 during a flight from Athens, Ohio to Madison VOR in Connecticut, thence to Millville VOR in New Jersey, and a landing at Atlantic City NAFEC. Portions of the return trip to Athens, Ohio were also recorded.

Loran-C GRI data frames were recorded using the 99600 U. S. Northeast Loran chain stations Seneca/Nantucket (TDA) and Seneca/Carolina Beach (TDB). GRI sequence number TDA and TDB were recorded as integer numbers, with the TD's in integer microseconds. Actual time-of-day can be determined from the data start time, plus the time per GRI and the sequence number.

The Ohio University low-cost Loran-C Receiver [1,2] was used to obtain the time-difference data for each GRI. Data was recorded on digital magnetic tape and post-processed into latitude and longitude using the Ohio University IBM System/370 computer.

This paper presents details of the Loran data base thus recorded, and provides information for data retrieval and use.

II. SUMMARY

A cross-country flight provided the opportunity for collection of nearly 170,000 Loran-C data frames using the 99600 U. S. Northeast chain. These data items have been formatted into two large data files for subsequent use in Loran receiver design and testing.

It is necessary to include a 'glitch' filter to remove the occasional blunder points which cause the position information to indicate impossible aircraft velocities. Fortunately, these points occur very seldom, and on the flight described in this paper, they occurred in isolated GRI frames, perhaps ten minutes or more apart.

A simple first-order tracking filter operating on 256 data elements provides satisfactory position data smoothing for overview plots, in the presence of normal aircraft maneuvers. This type of data filter has the advantage of easy implementation on an 8-bit microprocessor in a prototype receiver, and its smooth position outputs should allow a coordinate-conversion routine to operate in an asychronous mode, in the microprocessor background.

Coordinate conversion for the data base plots reported in this paper was accomplished post-flight on a general-purpose computer. The algorithm [3] operates successfully on the actual flight data; additional optimization is required before the FORTRAN-language algorithm can be transferred to the microprocessor in the Loran receiver.

A large data gap occurred near the Baltimore area, and it is felt the powerful NSS low-frequency transmitter in that area captured the high-gain preamplifier used for the Loran receiver. Future flight tests will utilize a more appropriate preamplifier to minimize overload problems.

The data collected and displayed as a result of this flight test provides encouragement to continue work in the envelope-tracking Loran-C receiver area. Specific future events should include:

1. Develop an integral software data filter for glitch removal and position smoothing in the receiver microcomputer.

2. Convert the coordinate-conversion routine for microprocessor execution in near-real time.

3. Perform future flight tests in a radar or DABS environment to provide absolute references for position and time.

4. Use a low-gain preamplifier to avoid overload on strong non-Loran VLF signals.

III. DISCUSSION

On January 9, 1979 the Ohio University DC-3 Flying Laboratory N7AP performed a cross-country flight from Athens, Ohio to the New York/New Jersey area, with a return flight to Athens the same day. The flight was conducted using Victor airways with normal ATC clearances and vectoring. The flight crew used VOR navigation throughout the flight. The complete flight plan is given in Table 1.

The flight was conducted for multiple purposes, with Loran data-collection being a passive, data-recording experiment. Meeting the principal objective of the flight involved maneuvers in the vicinity of Madison VOR northeast of New York and Millville VOR in New Jersey to evaluate VOR receiver operation. These maneuvers, particularly in the Madison VOR area, serve to illustrate the quality of Loran-C data collected.

The Loran-C experiment consisted of installation of the Ohio University high-gain, low-frequency preamplifier on the aircraft's ADF sense antenna, use of the Loran-C receiver described by Burhans[1,2] and the flight data package reported by Nickum,[4,5] modified to place GRI index and Loran-C time differences on the Kennedy 1600 digital magnetic tape recorder. Figure 1 shows the experimental configuration.

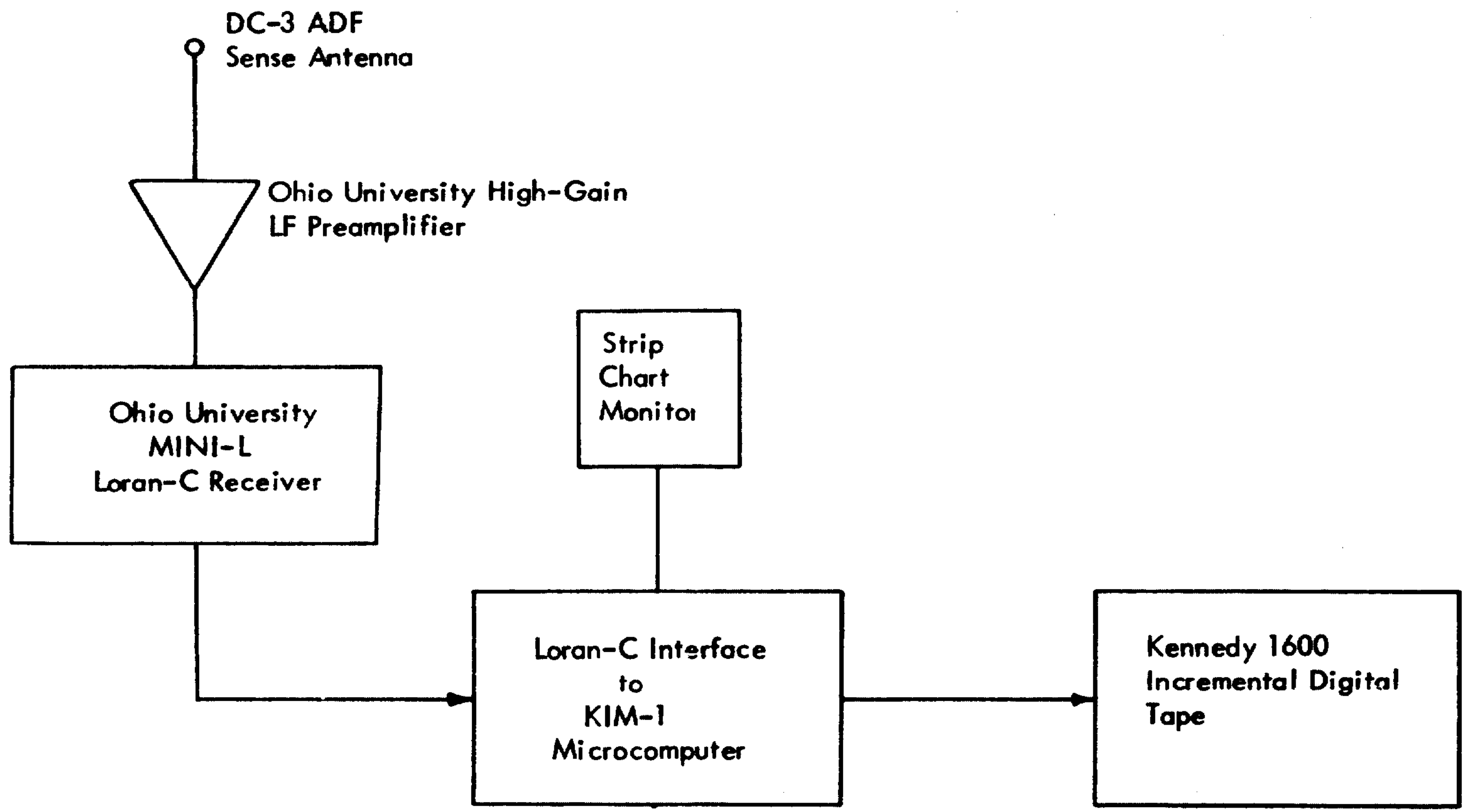

Figure 1. Experimental Flight Configuration.

January 9, 1979 - OUTBOUND	
08:55 Local	Depart UNI (Ohio University Airport)
09:14	Over PKB VOR at 6,000 MSL
09:21	Level at 9000 MSl, 21 nm E PKB
09:46	Over IHD VOR
09:57	Over JST VOR
10:10	Over TON VOR
10:16	Over PSB VOR
10:34	Over IPT VOR
10:53	Over LHY VOR
11:15	Over IGN VOR
Flight Maneuvers at MAD VOR: a. Track inbound on R310° b. Descend to 2000 MSL on R078° outbound c. Track inbound on R088° d. Track outbound on R244° for 10 nm e. Fly heading 095° to intercept R155° f. Track inbound on R155° g. Track outbound on R327° for approximately 15 nm	
11:36	First MAD crossing
11:52	Second MAD crossing
12:09	Third MAD crossing
12:32	Over CMK VOR
Flight continues, with maneuvers over MIV VOR, but no Loran-C data were recorded.	
13:55	Land at ACY/NAFEC
January 9, 1979 - RETURN	
15:05 Local	Depart NAFEC - Track inbound MIV R066° 1000' MSL
15:35	Over ENO VOR
16:04	Over BAL, level 3500 MSL
16:35	Over MRB, level 6000 MSL
17:25	Over MGW
18:06	Over PKB
18:35	Land UNI

Table 1a. Flight Documentation.

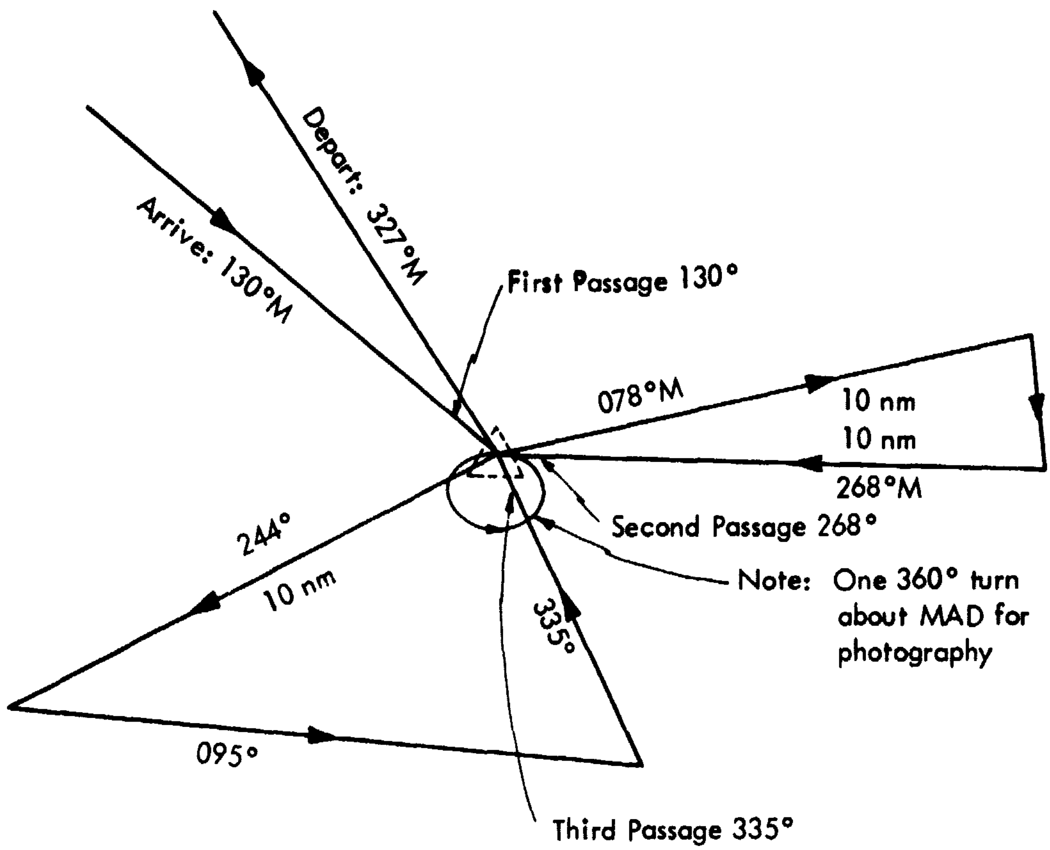

Table 1b. MAD VOR Flight Plan.

The Loran-C receiver and data package were configured to convert data from the U. S. Northeast chain (99600 GRI rate) to time differences with the least significant digit in microseconds, to double-buffer this data in micro-computer RAM and to drive the digital tape recorder. The experiment was run continuously throughout the flight, except for short periods required to change magnetic tape reels. During these outages, the flight data package ran continously so that the GRI index would continue to reflect real time.

The reader should be aware that the data presented in this paper are relative data, in that departures of the flight path from the nominal airways between VOR's are unknown. The data collected on this flight are intended for use in evaluating coordinate-conversion and filtering methods in the initial stages of navigation software development. Refinement of navigation software will take place using data referenced to ground radar or other positive references.

The author is encouraged, however, by the well-behaved nature of the data, to recommend continued investigation of envelope-tracking methods as used by Burhans [2] for low-cost Loran-C in the general aviation arena.

IV. DATA REDUCTION

A. Raw Data. Since the Loran-C data recorded in flight consisted of GRI index numbers and time differences, the description of the aircraft position in latitude/longitude required additional processing after the flight. It was decided to leave the LORAN data base in raw data terms, and to convert each raw data point to lat/long so that overall data quality could be assessed subjectively from a lat-long plot. Additionally, tracking filter parameters could be investigated for time-difference smoothing. These filter parameters would then be applicable to micro-computer software development for the real-time navigation routines.

The raw flight data are stored into two files: (1) the outbound flight from Athens, Ohio to the area of Madison VOR, and (2) the return flight from Atlantic City NAFEC to Athens. Raw data for these two files were taken from the Kennedy tapes and transferred to the System/370 for processing.

(1) Pre-Screening - The raw GRI and time-difference data elements were scanned for reasonability to check for presence of both time differences for each GRI and to eliminate blunder points at the beginning and end of tape files.

(2) Data Cleaning - To preserve the original data, including noisy points or glitches, only those data elements which were known to be in error due to operator action or data-collection system malfunction were removed. For example, in the outbound flight data, several GRI groups were removed due to a software buffering error which occasionally allowed the incoming Loran data to overrun the Kennedy recorder's maximum speed in incremental mode. The symptom in this case was data consisting of one or more missing GRI index numbers, followed by "orphaned" time-differences. The error did not affect subsequent GRI index values or time differences, and simply caused a short space of missing data.

Another group of data points was removed since the receiver was re-locked to a different LORAN-C chain for approximately thirty minutes to assess signal quality on this chain. Since the resulting data did not relate to other data in the file, it was removed.

(3) Reformatting - The remaining Loran-C data points were placed in a a FORTRAN unformatted-data file for user convenience and efficiency of storage. A FORTRAN subroutine for retrieving the data was written to facilitate file usage.

Table 2 gives a complete description of the resulting two raw data files for the outbound and the return flights. Figure 2 shows an overall digital plot of the entire data base, using a 100-point unweighted trailing average to determine each plotted point. This plot should be considered only an overview, or outline, of the entire data base. Note the data crowding near Madison VOR, where maneuvering was performed, and compare with the flight plan, Table 1b, for Madison maneuvers.

In Table 2, each data gap is listed together with time and position information. The larger gaps are also visible in Figure 2. The gaps in the outbound flight are explained by the software buffering error described above, except for one tape change and the receiver chain change to 99300. For the return flight, a large data gap appears in the Kenton and Baltimore areas. Upon investigation after the flight, it was found that the LORAN receiver had apparently been captured by an interfering signal, causing loss of lock and subsequent software failure. The data were removed from the data base since the data points were incapable of being reformatted for use. It was determined that the antenna preamplifier installed for this flight test was a high-gain model normally used with small, ground-based antennas. In the DC-3 installation, a large ADF sense antenna was used, and it is thought that the strong VLF station at Annapolis (NSS) overloaded this preamplifier. Future flight tests will be run using lower-gain antenna preamplifier units, and it is expected this problem will be resolved.

A tape change in the Morgantown area caused a small data gap.

V. DATA BASE USAGE

The Loran-C flight data base consists of two large files containing FORTRAN unformatted records. Table 3 gives the specifics:

File	GRI Frames Present	Bytes Storage
FT0179 OUTBOUND	102,878	1,667,200
FT0179 RETURN	61,927	1,017,600

Table 3. File Sizes.

Line	GRI	Time*	GEOGRAPHIC COORDINATES**		Notes
OUTBOUND - 102,878 GRI Records					
1	608-4937	00:16:00	39.4°N-	81.6°W	
2	4939-12899	00:23:12	39.5	81.2	
3	12901-43409	00:36:25	39.8	80.2	
4	43411-45100	01:27:03	41.1	77.7	
5	45102-52388	01:29:52	41.1	77.5	
6	52390-53156	01:41:58	41.4	76.7	
7	53159-53201	01:43:14	41.4	76.6	
8	53203-53203	01:43:19	41.4	76.6	Receiver switched to 99300 chain during this gap
9	70208-83933	02:11:33	41.7	74.5	
10	83935-91249	02:34:20	41.4	73.0	
11	91251-112799	02:46:28	41.4	72.4	Tape change caused data loss
12	114101-121797	03:24:24	41.4	73.1	
RETURN - 61,927 GRI Records					
13	185-9385	00:00:18	39.6°N-	74.8°W	
14	35672-69017	00:59:13	39.4	77.2	Interference in BAL area caused data loss
15	69020-72028	01:54:34	39.5	79.3	Tape Change
16	74701-84471	02:04:00	39.6	79.7	

* Time Since Takeoff at Beginning of Data Group.

** Loran-C Position Estimate at Beginning of Data Group.

Table 2. Data File Description.

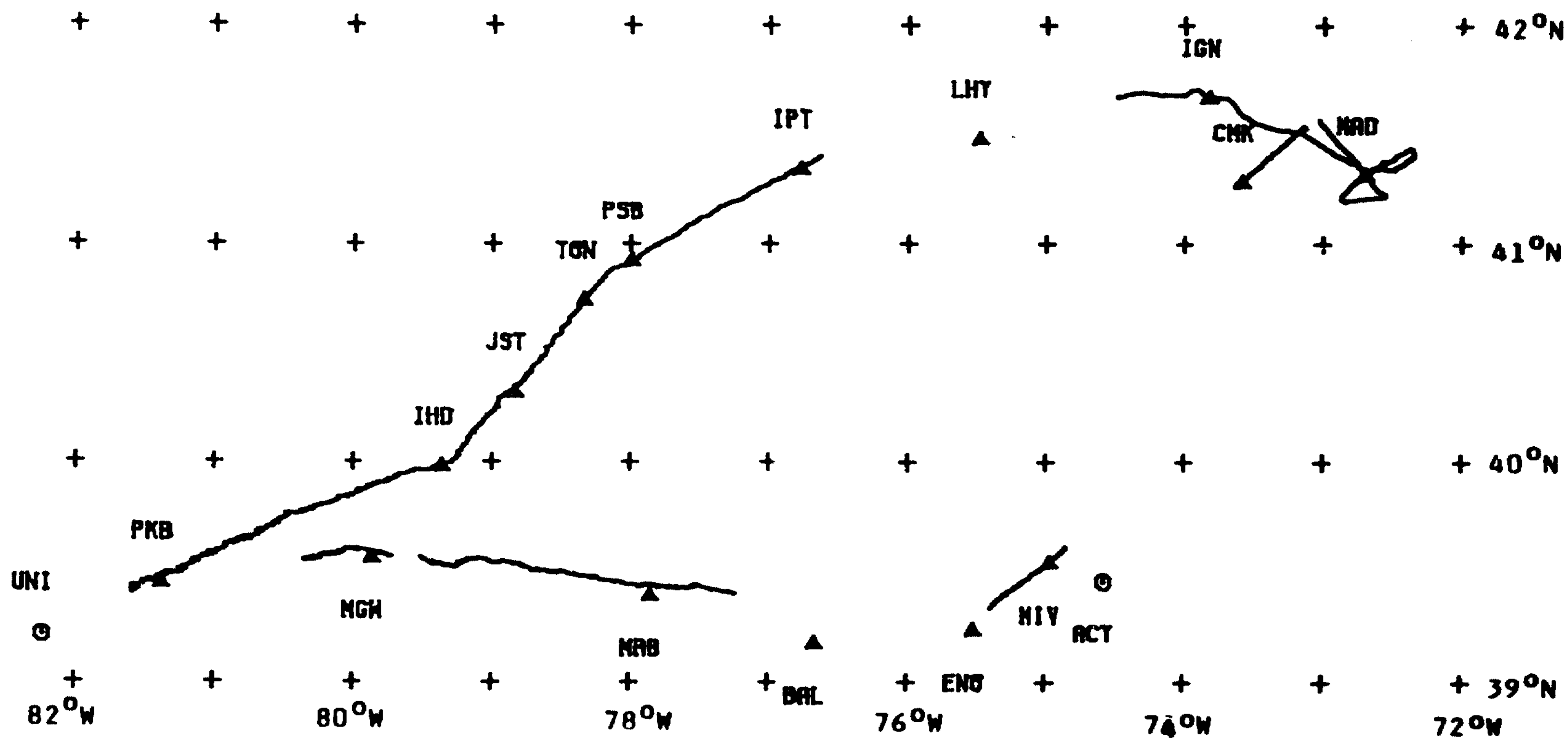

Figure 2. Loran-C Flight Data Base Plot.

Subroutine DBREAD has been written to facilitate file usage. In the user's program, one of two entries to this subroutine will access the data base:

CALL DBFIND (IGRI)

causes a search of the data base for the GRI index number IGRI. The record containing GRI index IGRI is made available. Note that since each record contains 100 GRI frames, index IGRI may not be the first frame received from DBREAD.

CALL DBREAD (IGRI, ITDA, ITDB)

retrieves the next sequential record from the data base. IGRI is the GRI index, and ITDA and ITDB are the time differences, in integer microseconds, for the 99600 chain station pairs Seneca/Nantucket and Seneca/Carolina Beach, respectively. The user must recognize the first occurrence of IGRI = 0, since this signifies the end of the data file.

The program listing for DBREAD appears in the Appendix to this paper.

VI. ACKNOWLEDGEMENT

The author acknowledges the direct support given by Joseph P. Fischer, NASA intern, in the reduction and plotting. Ralph Burhans, NASA Project Engineer, developed the Loran-C receiver front-end used for these tests, and James Nickum, NASA intern, built the data collection package.

VII. REFERENCES

[1] Burhans, R. W., "Phase-Locked Tracking Loops for Loran-C", Technical Memorandum (NASA) 60, Avionics Engineering Center, Ohio University, Athens, Ohio, August 1978.

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[4] Nickum, James, "Stand-Alone Development System Using a KIM-1 Microcomputer Module, Technical Memorandum (NASA) 56, Avionics Engineering Center, Ohio University, Athens, Ohio, March 1978.

[5] Nickum, James, "Loran-C Flight Test Software", Technical Memorandum (NASA) 61, Avionics Engineering Center, Ohio University, Athens, Ohio, August 1978.

VIII. APPENDIX

A. Program Listing for Subroutine DBREAD.

```
      SUBROUTINE DBREAD(IGRI,ITDA,ITDB)
C. READS LORAN DATA BASE FILES FROM FORTRAN FILE 10 AND GIVES
C. USER THE NEXT GRI DATA IN SEQUENCE.
C. *** USER MUST TREAT THE FIRST OCCURRENCE OF IGRI=0 AS END OF FILE.
      INTEGER L/0/
      INTEGER I(100),J(100),K(100)
      IF(L.EQ.0)GO TO 20
      L=L+1
      IF(L.GT.100)GO TO 20
   15 IGRI=I(L)
      ITDA=J(L)
      ITDB=K(L)
      RETURN
   20 READ(10,END=99)(I(N),J(N),K(N),N=1,100)
      L=1
      GO TO 15
   99 IGRI=0
      RETURN
      ENTRY DBFIND(IG)
C. THIS ENTRY READS RECORDS UNTIL FINDING THE RECORD CONTAINING
C. GRI COUNT IG. SUBSEQUENT CALLS TO DBREAD WILL OBTAIN DATA.
   30 READ(10,END=99)(I(N),J(N),K(N),N=1,100)
      L=1
      IF(I(1).LE.IG.AND.I(100).GE.IG)RETURN
      GO TO 30
      END
```