4722

1.0

1.1

1.25 1.4 1.6

2.8 2.5
3.2 2.2
3.6
2.0
1.8

INSTITUTE OF TECHNOLOGY

UNITED STATES AIR FORCE

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AN INVESTIGATION INTO THE NATURE
OF AIRCRAFT SUPPORTABILITY
IN THE CILC ENVIRONMENT

Gordon S. Luna, Captain, USAF
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LSSR 13-77B

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This paper deals with the initial development of a generalized
model representing the Centralized Intermediate Logistics
Concept (CILC). The model can handle from 1 to 10 operating
locations and many of the logistical variables including
demand rates, repair cycle times, travel times, and base
repair rates. The analysis includes a comparison of
the traditional maintenance system to CILC and a trend analysis
of the effects of demand rates, base repair rates, shipping
times, repair times, and location strategy on supportability.

LSSR 13-77B

AN INVESTIGATION INTO THE NATURE OF
AIRCRAFT SUPPORTABILITY IN
THE CILC ENVIRONMENT

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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Captain, USAF   Captain, USAF

September 1977

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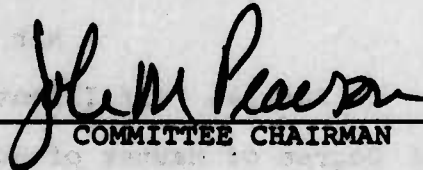
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and
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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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CHAPTER I

INTRODUCTION

In September 1975, the Deputy Chief of Staff for
Systems and Logistics, Headquarters United States Air
Force, issued Program Management Directive (PMD) L-Y5028.
The document established the Maintenance Posture Improve-
ment Program (MPIP) and charged the major commands with
investigating new methods of reducing maintenance man-
power and materiel costs and increasing mission support
effectiveness. One of the items included in the MPIP
was a requirement to analyze the feasibility of the
geographic centralization of intermediate level aircraft
maintenance. The requirement has led to the development
of the Consolidated Intermediate Logistics Concept (CILC)
(8:iii). Currently, field tests of the CILC are being
conducted by both Pacific Air Forces (PACAF) and Stra-
tegic Air Command (SAC). The interest demonstrated by
Headquarters Air Force and two operating commands in
increased future utilization of CILC represents a basis
for more extensive examination of the concept. Of prime
importance is the concept's impact on logistic support
for the affected bases.

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Statement of the Problem

The ultimate decision on the future of CILC will be made by managers at Headquarters USAF. The quality of that decision will be governed by information gathered from field tests and theoretical studies and made available to the decision maker. To date, all tests and most research have been directed toward specific scenarios. A need exists to investigate the effect of CILC upon a general operational scenario. This general approach may provide an addition to the existing CILC information and afford a higher probability of an appropriate decision on utilization of CILC. The problem for research, then, is stated as: *A need exists to investigate the general relationship between a CILC environment and aircraft supportability.*

Background

Description of CILC

Under the traditional Air Force maintenance concept, three related maintenance echelons exist: field, intermediate, and depot, with field and intermediate echelon units stationed at each flying location. The lowest or organizational echelon is "that category of maintenance actions which is normally the responsibility of and performed by a using organization on its assigned equipment [15:12]." The second or intermediate echelon is "that category of maintenance actions which is normally the

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responsibility of and performed by designated maintenance activities for direct support of the using organization [15:11]." The highest or depot echelon is:

> That category of maintenance actions . . . to support organizational and intermediate maintenance activities by more extensive shop facilities and equipment and personnel of higher technical skill than are normally available at the lower levels of maintenance [15:10].

Since each base accomplishes its own intermediate level maintenance, considerable time, money, and knowledge are invested in each intermediate level maintenance facility.

The CILC represents a departure from the traditional method of accomplishing intermediate aircraft maintenance. Normally, each base attempts to achieve 100 percent self-sufficiency at both field and intermediate maintenance levels. CILC would consolidate the intermediate maintenance capability of two or more bases at one location termed the Consolidated Intermediate Repair Facility (CIRF). Under the concept, each base would retain its field level maintenance capability but would transfer its intermediate level maintenance assets and personnel to the CIRF (7). Maintenance at the bases, referred to as operating locations (OLs), would be reduced to line replaceable unit (LRU) maintenance, i.e., isolation and replacement of LRUs. All major component repair would be accomplished at the CIRF and the depot responsibility would remain unchanged (10:2). Although CILC is

not a new concept, it has received recent attention as a
result of PMD L-Y5028.

Part of the current rationale supporting CILC
is based on the complexity and expense of modern weapons
systems and their associated logistic support equipment
(1:1). Another argument concerns the possible reduc-
tion in vulnerability of the support forces and equip-
ment since they would be located in more secure areas
or at least separated from the OLs (3:5). However, prior
to large-scale application of the concept, an intensive
investigation must be performed and field tests (PACAF
and SAC) must be evaluated.

PACAF Field Test

In the PACAF field test, Kadena Air Base, Japan,
is one of three operating locations and host to the CIRF.
The two other OLs, Kunsan Air Base, Korea, and Osan Air
Base, Korea, are entirely dependent on Kadena for all
intermediate F-4E maintenance support. Interim results
indicate that CILC is a feasible concept and provides an
acceptable level of support and other significant, intan-
gible benefits, i.e., increased personnel tour stability
and reduced vulnerability of facilities to hostile forces.
As in all field tests, PACAF has encountered some problem
areas but none are perceived to be of sufficient magni-
tude to warrant rejection of the concept (7).

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SAC Field Test

The SAC field test is currently being conducted in the south-central United States with Barksdale Air Force Base, Louisiana, as an OL and host to the CIRF, and Seymour-Johnson Air Force Base, North Carolina, and Warner-Robbins Air Force Base, Georgia, as the remaining OLs. An interim report has not been published, precluding a comparison of the B-52/KC-135 scenario with the PACAF F-4E scenario. However, SAC personnel associated with planning the test and involved in initial operations, support the interim PACAF test conclusions concerning feasibility (16). In addition to the field tests, theoretical analyses are being conducted.

Theoretical Analyses

RAND Studies. The RAND Corporation has been involved in several studies of the CILC concept. Dr. John Lu led a study of the F-4E Northern Pacific scenario and examined:

1. The impact of a centralized repair operation on spares requirements

2. A supply system that would be more consistent with the centralized maintenance posture (8:1)

Dr. Lu's conclusions indicated that both stockage and shipping requirements would be a function of three variables:

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1.   Order and shipping times between OLs and the CIRF

2.   The percentage of reparable items the CIRF could effectively repair

3.   The policies for stock distribution between OLs and the CIRF (8:14-15)

Another RAND Corporation study, conducted by Dr. Morton B. Berman et al. (3), tested the feasibility of the CILC primarily in a European F-4 scenario. This investigation examined:

1.   The CILC environment through the application of existing Air Force regulations on management, maintenance, and supply requirements

2.   The impact of CILC on manpower, bench equipment, supply requirements, transportation requirements and facilities (3:6)

The conclusions from this study were:

1.   That there is a requirement for more stock in the supply system

2.   That there is a requirement for increased transportation

3.   That there are certain variables whose value cannot be supplied through historical data from the current structure: e.g., the exact numbers for shipping times, base repair cycle times, and the productivity of workers (3:25)

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The third RAND Corporation report was based on a study accomplished by Dr. John A. Muckstadt, Cornell University, acting as a consultant for RAND. This study involved the formulation of and experimentation with a computerized three-echelon supply system model based on the F-15 aircraft scenario. The objective of the study was to optimize stockage quantities for a given level of funding that could be employed in conjunction with CILC. The conclusions reached by Dr. Muckstadt included the following:

1. An increase in Line Replaceable Unit (LRU) investment may result in a decrease in Shop Replaceable Unit (SRU) investment due to regional control of CIRF assets

2. Maintenance delays may be induced by the degree of investment in maintenance resources at each OL as a result of the percentage of reparable assets that can be repaired at the CIRF

3. A similar effect may be induced by Repair Cycle Times (RCT)[1] (10:32-36)

PACAF Simulation Study. Mr. Robert M. Malis (9) has developed and used a simulation model of the PACAF CILC environment. His work has been directed at the examination of:

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[1]Repair Cycle Time--Time required to repair a defective part (9:9).

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1. The effectiveness of traditional methods of spares allocation

2. The effects of variations in fundamental maintenance and supply variables

3. The development of a supply stockage strategy suitable for automatic computation of supply stock levels

4. The required additional investment in spares to obtain CILC support equal to the traditional system (9:8)

The conclusions/observations of this report included:

1. Travel time must not exceed three days

2. Distributions of shelf stock should favor Kunsan and Osan

3. Increase in total system stock (10 to 15 percent) is required for CILC to equal the support furnished by the traditional system

4. A "directed allocation"[2] supply distribution system is superior to a "requested allocation"[3] supply distribution system.

---

[2]"directed allocation" supply system--implies the CIRF retains no stock. The CIRF decides where to ship each unit as it becomes serviceable.

[3]"Requested allocation" supply system--implies the CIRF would stock serviceable units. The OLs decide when to order a unit based on their needs.

The studies and the field tests imply that CILC can be a viable approach to intermediate maintenance. However, the general nature of the CILC environment has yet to be explored and that is the object of this research.

Research Question

What is the nature of the relationship between the CILC environment and aircraft supportability?

Research Objectives

1. Determine the pertinent variables in the CILC environment

2. Build a generalized heuristic model of the CILC environment

3. Compare the traditional maintenance system to the generalized CILC environment

4. Determine the relationships between the variables found in the CILC environment and supportability

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CHAPTER II

METHODOLOGY

In support of the research objectives, methods were developed to select the pertinent variables for study, to observe the impact of the variables on supportability, to compare the traditional maintenance system with the generalized CILC environment, and to determine the interaction between the variables and supportability. The following sections discuss these areas.

Selection of the Variables

In a complex, multi-faceted maintenance environment, more variables exist than can be measured and included in a study of this type. Therefore, the decision was made to select those variables identified in previous studies as significantly influencing supportability, and those which were theorized to become influential in the generalized study.

Variables identified in previous studies were:

1. Repair Cycle Time (RCT)

2. Order and Ship Time (OST)

3. Travel Time

4.　Percent Base Repair (PBR)

　　　　5.　Daily Demand Rate (DDR)

Malis observed that RCT, OST, and DDR were included in
stock leveling formulas and were, therefore, important
to supportability (9:14). Additionally, Both Lu and
Berman identified RCT and OST as significant in deter-
mining stockage requirements in CILC, with RCT being,
perhaps, the "most crucial" variable (3:25) (8:14).
In his study Malis noted that travel time, being
integral to both RCT and OST, would be an important
variable in determining supportability of the CILC
environment (9:13). Also indentified was the pro-
portion of reparables repaired by the CIRF.

> Since the presumption is that accomplishing
> repair at the CIRF takes considerably less time
> than at the depot, increasing the percent of
> base level [CIRF] repair would have a beneficial
> effect on spare requirements (1:14).

In addition, another variable--number of OLs--was deter-
mined to assume increased significance in the study of
the generalized CILC environment.

　　　　In considering the increase in the number of
OLs ir a generalized CILC environment, two effects
became apparent: the increased workload of the CIRF,
and the additional support for the system of OLs through
lateral borrowing. Previous studies omitted discussing
the effects of increasing the number of OLs. However,

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in the study of the generalized CILC environment, this
-variable was thought to assume increased importance. It
was decided, therefore, to include the number of OLs as
a variable for study.

Development of Scenarios

Specific scenarios were employed for two reasons:
to facilitate observation of trends in supportability as
generated by the chosen variables and to provide the
study with an element of realism. By employing scenarios,
multiple situations could be studied simultaneously from
differing vantage points (number of OLs, PBR, DDR, etc.);
it was a method for minimizing experimentation while study-
ing several effects simultaneously. As with prior studies,
this effort was application oriented.

Since Berman had begun studies of the CILC environ-
ment in Western Europe and a field test had not been
employed, this area was selected as the subject area. In
this study no specific weapons system was visualized.
·Also, nine bases were selected as OLs of the hypothetical
CILC environment: Zweibrucken, Ramstein, Bitburg, Spang-
dahlem, Hahn, Soesterberg, Woodbridge, Bentwaters, and
Alconbury. The physical layout is illustrated in Figure 1.
More important than the physical layout were the trans-
portation relationships employed in the study. These
are illustrated in Figure 2. Travel times and schedules

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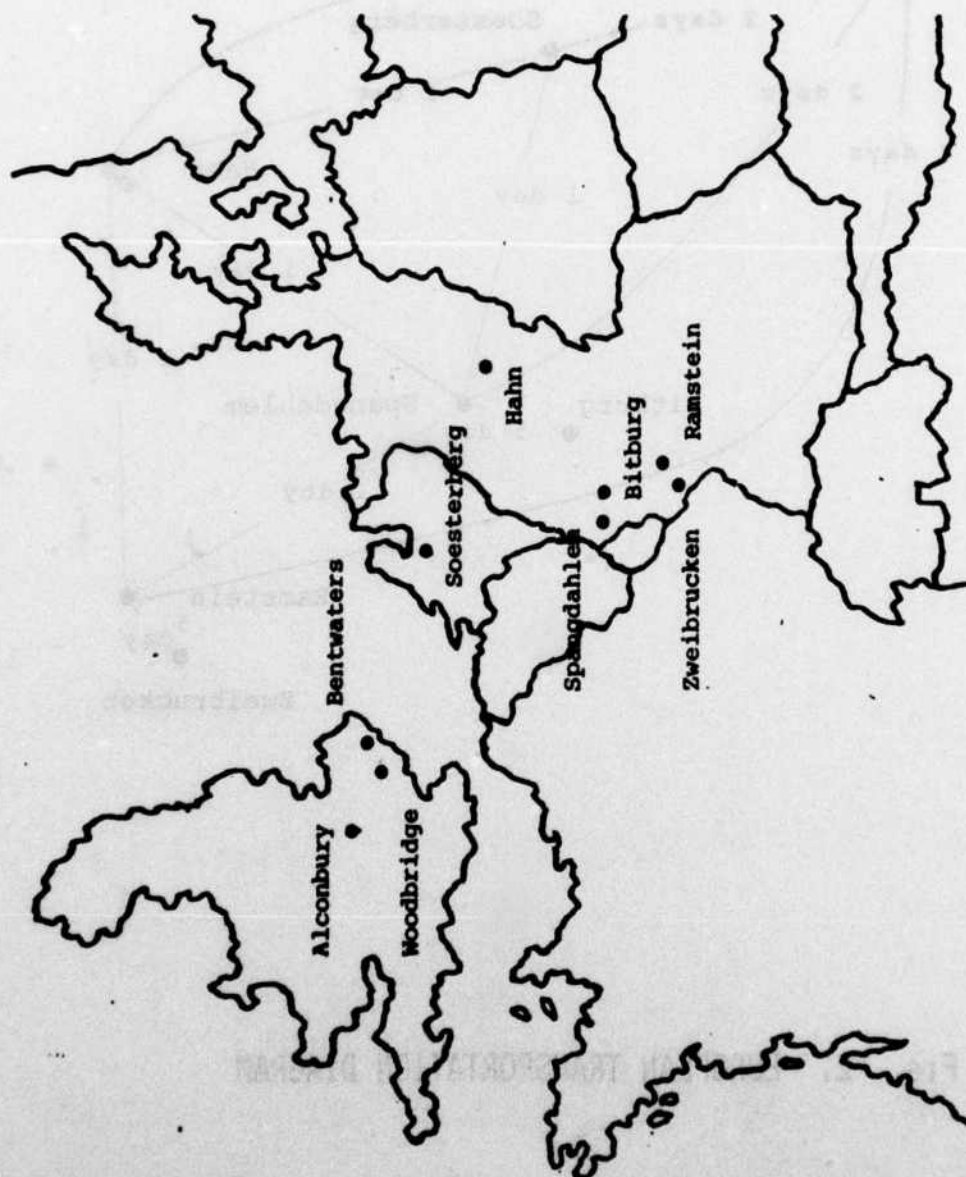
FIG. 1. EUROPEAN CILC SITUATION

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Alconbury

← 1 day →   Bentwaters

1 day   .5 day
Woodbridge —— 2 days

2 days —— Soesterberg

2 days   1 day

2 days   1 day

Hahn

1 day

1 day

Bitburg   Spangdahlem
●.5 day

1 day

Ramstein
.5 day
●

Zweibrucken
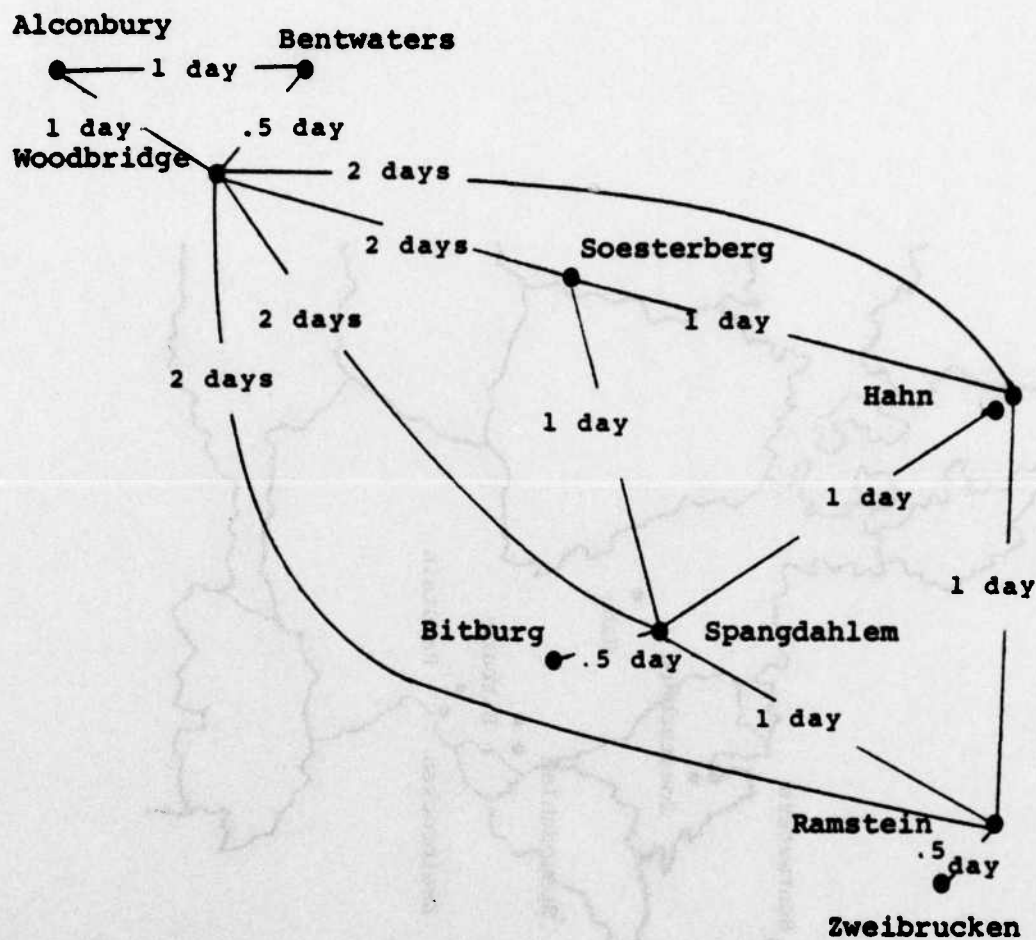
Fig. 2. EUROPEAN TRANSPORTATION DIAGRAM

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were developed to reflect realistic transportation capabilities. The following is a summary of the transportation relationships of the layout:

1. Double wing at Hahn (equivalent to two OLs with no transportation time between them)

2. .5 day travel time between: Spangdahlem and Bitburg, Ramstein and Zweibrucken

3. Alternate day air service between Woodbridge and the OLs illustrated on the continent

4. Daily transportation between all other Ols

For the study, four basic situations were employed corresponding to three, six, seven, and ten OLs. In addition, to investigate the effect of travel time between OL and CIRF, CIRF locations were established at Woodbridge, Soesterberg, Hahn, Spangdahlem, and Ramstein (Table 1). This brought to twenty the total number of scenarios in the study. In his study, Berman discussed the security aspects of the noncollocated CIRFs in Europe. The present effort was designed so that the CIRFs could be studied either collocated or noncollocated with the OLs (3:17) Tables 2 and 3 depict the scenarios and coding used in the study.

TABLE 1

CIRF LOCATION DESIGNATIONS

Location	CIRF Location Number
Woodbridge	1
Soesterberg	2
Hahn	3
Spangdahlem	4
Ramstein	5

TABLE 2

OL ENVIRONMENTS IN THE STUDY

Number of OLs	OLs Included
3	Ramstein, Zweibrucken, Spangdahlem
6	Ramstein, Zweibrucken, Spangdahlem, Bitburg, Hahn (2)
7	Ramstein, Zweibrucken, Spangdahlem, Bitburg, Hahn (2), Soesterberg
10	Ramstein, Zweibrucken, Spangdahlem, Bitburg, Hahn (2), Soesterberg, Woodbridge, Alconbury, Bentwaters

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TABLE 3

SCENARIOS IN THE STUDY

CIRF Location	Number of OLs
1	3
"	6
"	7
"	10
2	3
"	6
"	7
"	10
3	3
"	6
"	7
"	10
4	3
"	6
"	7
"	10
5	3
"	6
"	7
"	10
Traditional Maintenance System	3
	6
	7
	10

The Simulation

To observe the impact of the variables on sup-
portability, the Malis PACAF Simulation was selected.
The advantages of computer simulation were enumerated
by Beer:

> First . . . Simulation provides artificial
> experience of the real system very much more
> quickly than it could otherwise be obtained . . .
> Secondly, the experience is gained without running
> any risks. If we want to know what the system
> does under a particular set of circumstances,
> this can be readily discovered without putting
> the real-life system to the trouble and expense
> of running a trial which may in many cases prove
> disastrous. Thirdly, it is possible to alter
> the system as it now is, to see what would be
> likely to happen to it under a new kind of regime;
> and this may also be done without jeopardizing the
> success of an existing profitable situation [2:231].

The Malis Simulation was selected for its adaptability
and validity. This simulation could be generalized to
accomodate more than three OLs. Additionally, the sim-
ulation had been utilized by PACAF for approximately one
year and had been employed in investigating the affect
of policy changes concerning frequency of airlift and
WRSK stockage (9:29). Changes to be made to the sim-
ulation were relatively few.

To adapt the Malis Simulation to this study two
modifications were made: the number of OLs capable of
being handled, and the lateral distribution policy. The
maximum number of OLs that the simulation could handle

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was increased from three to ten. The determination was made that ten OLs appeared to be a realistic upper limit to the simulation for two reasons. First, in reviewing the physical layout of bases that shared like weapons systems both overseas and in CONUS, few systems exceeded ten bases (13). Second, the establishment of a CIRF to service more than ten OLs would approach the scale of a depot; this would defeat the purpose of the CILC concept (5). The second modification concerned lateral borrowing of LRUs.

The lateral borrowing policy of the Malis Simulation stated that assets would be borrowed from the OL with the largest stock on hand. In dealing with the three OLs of the PACAF scenario this was a realistic policy. However, with as many as ten OLs, an additional requirement of proximity was included (11). This policy would more realistically simulate the policy actually employed in lateral borrowing of assets. The policy, then, was to choose the closest OL with the largest stock on hand.

Simulation Performance Measurement Criterion

In the traditional supply/maintenance system, two statistics have been employed to monitor supportability at each base:

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1. Aircraft Not Operationally Ready Supply
(NORS) Hours--the number of aircraft hours lost from
mission duties due to the aircraft being "not operation-
ally ready due to supply." If the figure becomes exces-
sively high it is cause for alarm within the management
structure (9:11).

2. Back Order Rate (BOR)--the percentage of
demands, LRU failures, which cannot be immediately sat-
isfied by issuing a replacement from shelf stock or bor-
rowing from the WRSK. A demand resulting in the lateral
transfer of an LRU from another base or from the CIRF
would constitute a backorder or item-NORS even though
the aircraft would not be technically NORS. In addition,
a true aircraft-NORS condition, where no replacement is
available from any source without waiting for one to be
returned from the CIRF, would also be a backorder. The
only quantitative judgment concerning the BOR found in
AFR 67-1, Vol. II, Part II, Chapter 11, is that perform-
ance is to be considered adequate if the base BOR for
all LRUs does not exceed 15 percent (9:12).

Both aircraft-NORS hours and base backorder
rates suffer from a common problem: They are aggregated
over all LRUs and do not yield LRU-specific information.
Aircraft-NORS hours tell little about the causes of the
delay, and BOR tells nothing about the number of back-
orders in the system or how long they persist. The

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statistic employed by the simulation eliminates these
difficulties.

The simulation measure of supportability is unsa-
tisfied demands (UD)[*] and is expressed by the following
equation:

$$A = \frac{\left(\sum_{i=1}^{n} t_i \right)}{T}$$

where: A = Time-weighted average UD

n = Number of UDs observed

t_i = Duration of UD

T = Total simulation time (9:12-13)

The UD figure reflects not only the number of unsatis-
fied demands existing per OL but also incorporates the
time delays for each demand.

BOR does not necessarily correlate with UD. For
example, at low DDRs, low UD figures and very high BORs
can be observed. In such cases, a zero stock level might
be permissible so long as service delays are short. A
BOR of 100 percent is insignificant if service times are
short and demands are observed once every six months.

---

[*]UD is an identical criterion to Sherbrooke's
backorder criterion (14:6).

Conversely, at high DDRs, a BOR of 15 percent could be disastrous if it requires thirty days to fill every back-order. Thus, in a system simulation where the concern is not with the problems of altering reporting procedures, UD is a superior criterion for system supportability (14:6).

Simulation Run Time

In a stochastic simulation which simulates performance over a period of years, exact results are neither predicted nor expected. Consequently, two alternatives are available to the researcher: allow a simulation run time sufficiently long so that enough observations are collected for statistical analysis of the experiment, or have a run time representative of the length of time policies are in effect and accept fewer observations for the study. In his simulation, Malis was interested in the statistics of the environment. Consequently, he required the quantity of observations provided by a long run time; the time chosen was approximately fifty-four years. For this study, a simulation run time of fifty-four years was excessive.

To gain an understanding of the nature of CILC variables and their effects on the CILC, a three year simulation was employed. This was more representative of time that policies are in effect (6). Therefore,

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results were not tabulated as precisely as in the Malis

study due to sensitivity of UD to specific events; trend

analysis was to be the result of the study.

Determination of the Relationships
Between Variables and Supportability

The study was divided into two segments: com-

parison of the traditional system and CILC environment,

and an investigation of the chosen variables' effects

on the generalized CILC environment. Because prior

studies had concluded that more assets would be required

to maintain equivalent performance in the CILC environ-

ment as opposed to the independent environment, it was

decided to investigate this for the generalized CILC

environment. A baseline set of variable values was

employed as follows: RCT: 4 days,

OST: 17 days,

PBR: 75 percent,

DDR: .1 demands per day.

These values were taken from the PACAF field test of F-4s.

Although this study was not weapon system specific, selec-

tion of these values insured that they were representative

of a realistic system for a baseline. Recent PACAF field

test results indicate RCT in the CILC environment is

greater than in the traditional system (4:27). Conse-

quently, it was decided to compare results of the

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traditional system with an RCT of four days against the
CILC environment with varying RCTs. Selection of the
baseline value simulations were run on the traditional
system's cases for three, six, seven, and ten bases and
on all twenty scenarios previously selected. Eighty-
four simulations were run and results were then exam-
ined by plotting the number of OLs vs. unsatisfied demand
per OL, with number of OLs being the independent variable.
After the independent to CILC comparisons were performed,
the selected variables were examined.

To examine the variables in the CILC environment,
all selected variables were exercised. Since the twenty
scenarios were designed to examine travel time and num-
ber of OLs, only four variables were required to be
exercised. Simulations were designed to run each sce-
nario over a representative range of values for each
experiment. Five values were selected for each variable
that included its baseline value. In comparison to the
Malis study, each variable range was at least 50 percent
of the observed test values (9:22). The values were
selected from the upper 50 percent of the observed values;
consequently, it was expected that the results for all
variables except PBR would be conservative. A total of
400 simulations were run for this portion of the study.
The values of the four variables were:

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OST: 15, 16, 17, 18, 19 days
PBR: 75, 80, 85, 90, 95 percent
DDR: .05, .1, .15, .2, .25 demands per day
RCT: 3, 4, 5, 6, 7 days

CHAPTER III

NATURE OF THE GENERALIZED SIMULATION

Description of the Population

The population considered for this study was
all UD generated by the generalized CILC simulation.
To provide a common reference the total system UD was
divided by the number of OLs in the environment to
render UD per OL. In this manner the environment of
ten OLs could be compared to that of three.

Assumptions

The following assumptions were incorporated
into the study:

1. LRU failures followed a Poisson distribution

2. Lateral support would be rendered whenever
possible

3. A peacetime environment existed--this was
a worse case situation for stockage since LRUs could
not be laterally borrowed from WRSKs

4. A uniform distribution existed for the
following variables:

Travel time (± 5 days)

PBR (± 50 percent)

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RCT (± 50 percent)

OST (± 50 percent)

5. There was no cannibalization of LRUs from other aircraft at an OL

6. There was no waiting to repair at the CIRF or depot, i.e., no batch processing or awaiting parts

7. Demand was stationary over the simulation period

8. There was no releveling for the CIRF environment. Since there was no acceptable CIRF releveling formula available at the time of the study, none was used (4:27)

9. An OLs WRSK could be reduced to zero by internally generated requirements. In reality, this would rarely be allowed to occur (6:40)

10. Values for DDR were identical for all OLs; all OLs had a similar number of aircraft and flying missions

Policies

The following policies were employed in the simulation:

1. Distribution of assets to OLs was made according to the following priorities:

NORS (oldest first)

WRSK deficits

Stock incrementing

28

2.   There was no stock maintained at the CIRF.
This was in accordance with the Malis findings that a
"directed" system was more efficient than a "requested"
system (6:29)

3. For the traditional system only, the
standard Air Force ninety day stock releveling policy
was applied. This is the procedure currently employed
for minimizing stock at base level.

CHAPTER IV

FINDINGS AND OBSERVATIONS

Paralleling methodology, analysis of the simulation scenarios was divided into two parts: The analysis of the traditional system vs. CILC environment, and the analysis of the CILC scenarios to determine trends and variations.

Traditional System Vs. CILC Environment

As described in the methodology, simulation runs of the traditional system, with an RCT of four days and baseline values of the other variables, were compared to the CILC environment of varying RCTs. With a CILC RCT of four days, resultant UDs are illustrated in Figure 3.[1] It can be seen that the traditional system produced higher UDs for all but three of the twenty scenarios of the CILC environment. These exceptions were CIRF locations 1 and 2 when servicing three OLs, and CIRF location 1 when servicing six OLs. Aside from the

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[1]The sole operational difference between the traditional system and CILC environment was that in the traditional system intermediate level repair was accomplished at the individual bases and the tradition system incorporated stock releveling.
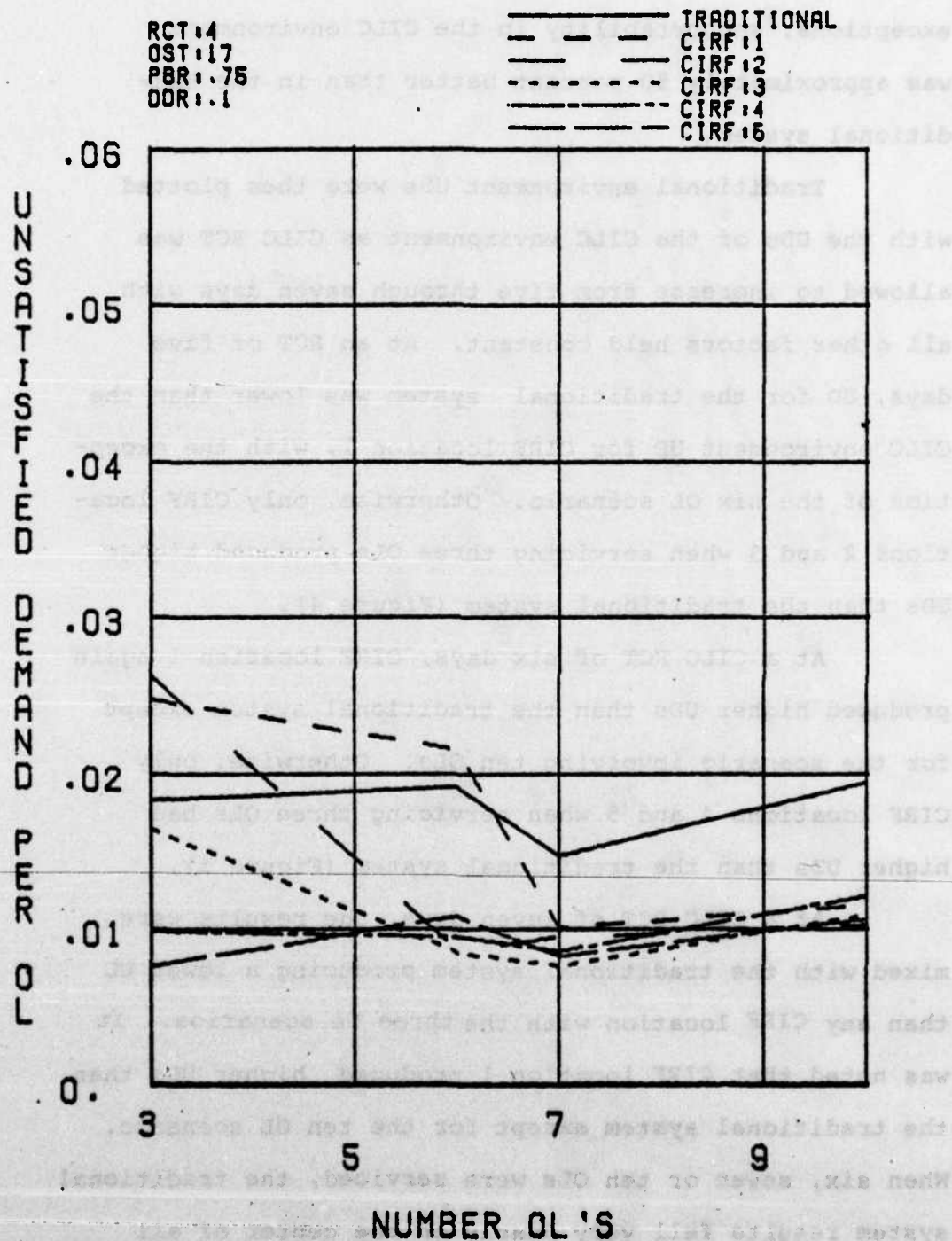
30

FIG. 3. TRADITIONAL VS CILC/RCT:4

exceptions, supportability in the CILC environment was approximately 50 percent better than in the traditional system.

Traditional environment UDs were then plotted with the UDs of the CILC environment as CILC RCT was allowed to increase from five through seven days with all other factors held constant. At an RCT of five days, UD for the traditional system was lower than the CILC environment UD for CIRF location 1, with the exception of the six OL scenario. Otherwise, only CIRF locations 2 and 3 when servicing three OLs produced higher UDs than the traditional system (Figure 4).

At a CILC RCT of six days, CIRF location 1 again produced higher UDs than the traditional system except for the scenario involving ten OLs. Otherwise, only CIRF locations 4 and 5 when servicing three OLs had higher UDs than the traditional system (Figure 5).

At a CILC RCT of seven days, the results were mixed with the traditional system producing a lower UD than any CIRF location with the three OL scenarios. It was noted that CIRF location 1 produced higher UDs than the traditional system except for the ten OL scenario. When six, seven or ten OLs were serviced, the traditional system results fell very nearly in the center of all CILC location results (Figure 6).
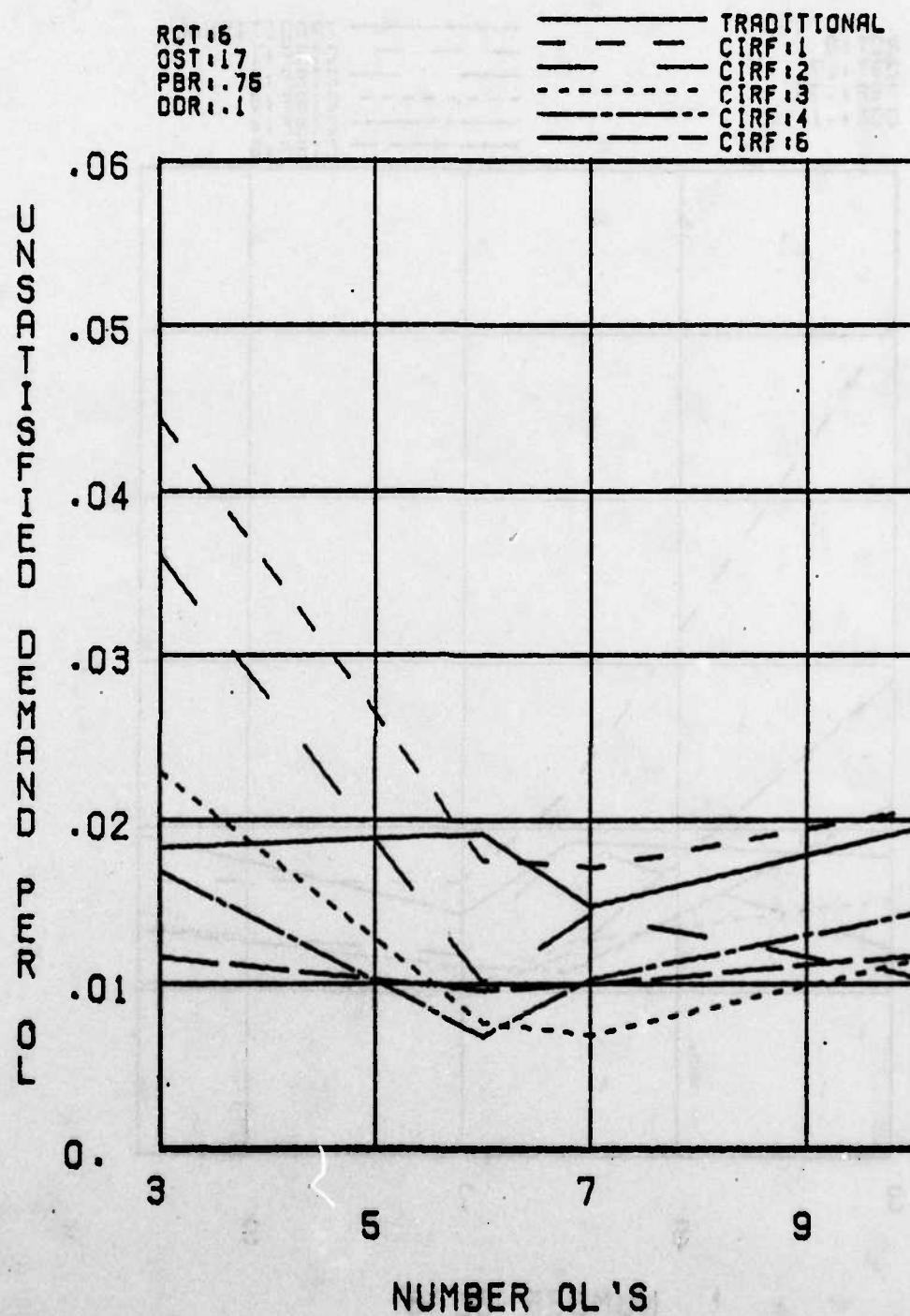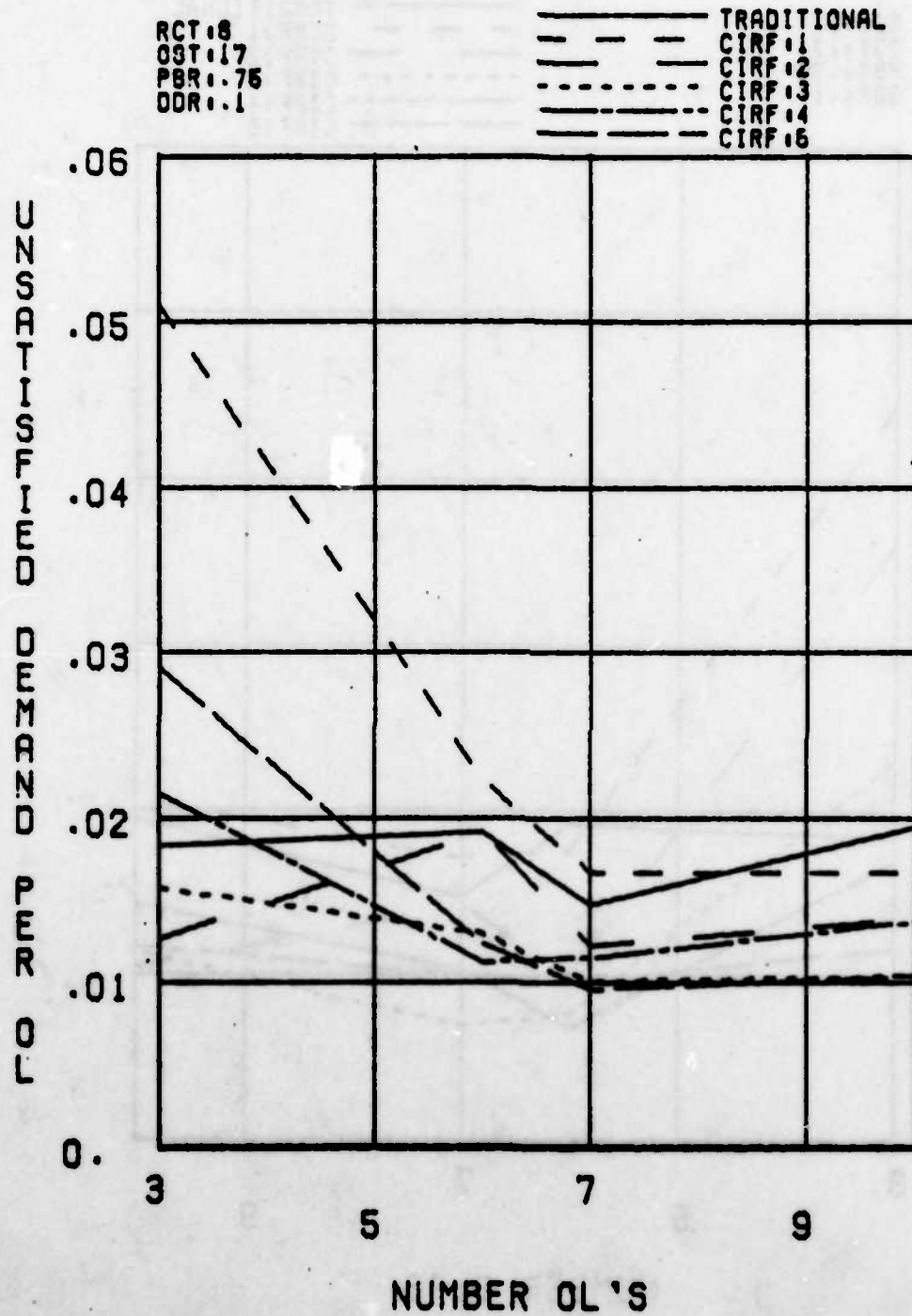
Fig. 4. TRADITIONAL VS CILC/RCT:5

33

RCT:6
OST:17
PBR:.75
DDR:.1

Legend:
— TRADITIONAL
— — CIRF:1
—— CIRF:2
···· CIRF:3
—·— CIRF:4
—·· CIRF:6

UNSATISFIED DEMAND PER OL
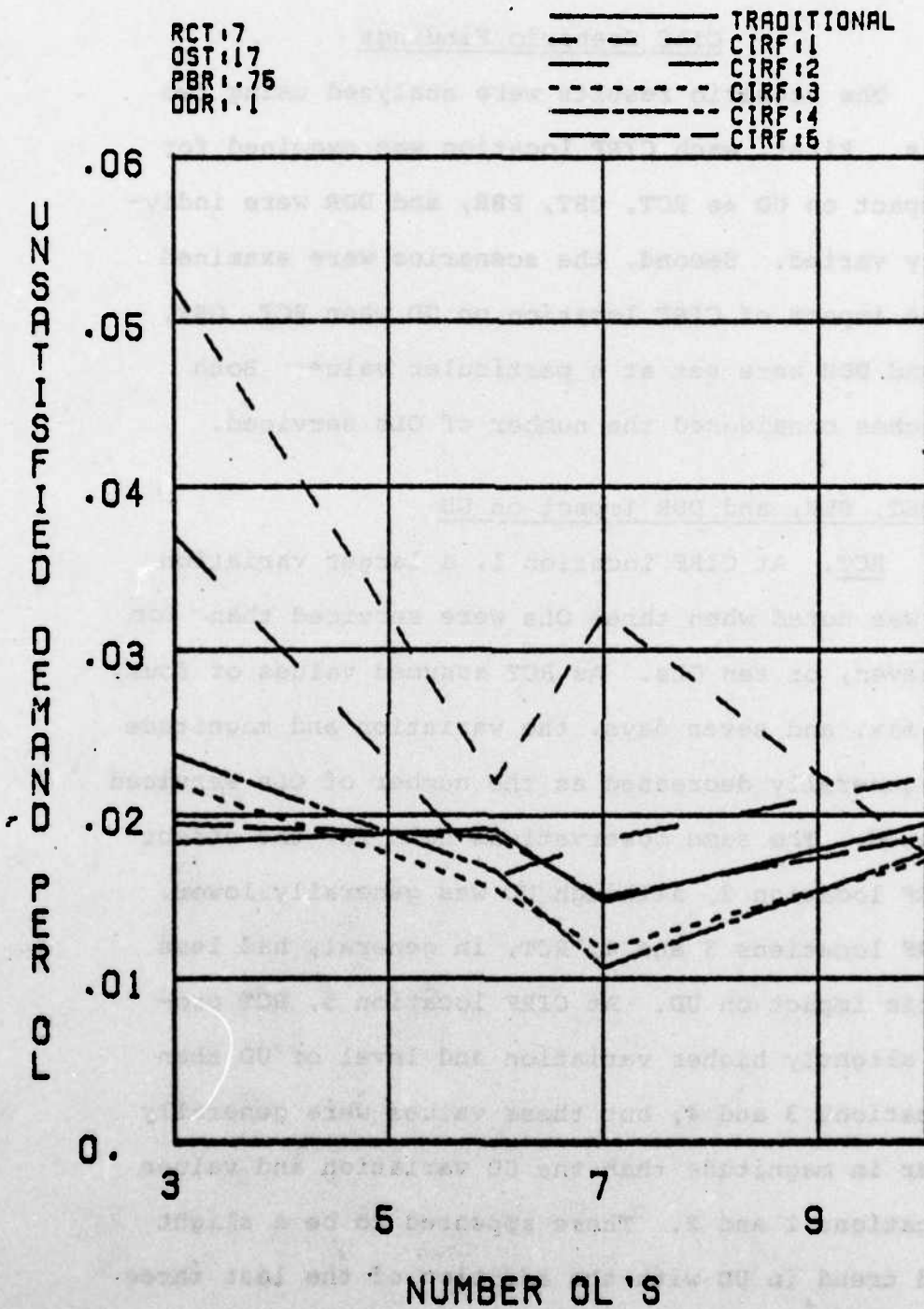
NUMBER OL'S

FIG. 5. TRADITIONAL VS CILC/RCT:6

34

FIG. 6. TRADITIONAL VS CILC/RCT:7

CILC Scenario Findings

The scenario results were analyzed using two methods. First, each CIRF location was examined for the impact on UD as RCT, OST, PBR, and DDR were individually varied. Second, the scenarios were examined for the impact of CIRF location on UD when RCT, OST, PBR, and DDR were set at a particular value. Both approaches considered the number of OLs serviced.

RCT, OST, PBR, and DDR Impact on UD

RCT. At CIRF location 1, a larger variation in UD was noted when three OLs were serviced than for six, seven, or ten OLs. As RCT assumed values of four, five, six, and seven days, the variation and magnitude of UD generally decreased as the number of OLs serviced increased. The same observations held for the effect on CIRF location 2, although UD was generally lower. At CIRF locations 3 and 4, RCT, in general, had less dramatic impact on UD. At CIRF location 5, RCT produced slightly higher variation and level of UD than at locations 3 and 4, but these values were generally smaller in magnitude than the UD variation and values at locations 1 and 2. There appeared to be a slight upward trend in UD with the addition of the last three OLs to CIRF locations 2 through 5. In general, the

36

impact of RCT on UD was evident at all CIRF locations regardless of the number of OLs serviced (Figure 7-11).

OST. OST had the greatest impact on UD at CIRF location 1 when only three OLs were serviced; there was wide variation in UD as OST ranged from fifteen to nineteen days. However, at all other CIRF locations, in addition to CIRF location 1 with six, seven, or ten OLs serviced, UD varied little as a result of OST. Likewise, there was little variation related to number of OLs serviced. An upward trend in UD with the addition of the last three OLs to any CIRF location was also noted (Figure 12-16).

PBR. At CIRF location 1, the value and variation in UD as a result of PBR was greatest when three and six OLs were serviced. At CIRF location 2, UD was highest when three OLs were serviced and the variation in UD was less pronounced than CIRF location 1 for all numbers of OLs serviced. At CIRF locations 3, 4, and 5, there was slightly more variation in UD than at CIRF location 2. At all CIRF locations, a 20 percent reduction in PBR produced as much as an 80 percent increase in UD. At CIRF locations 2 through 5, the additions of the last three OLs produced an upward UD trend (Figure 17-21).
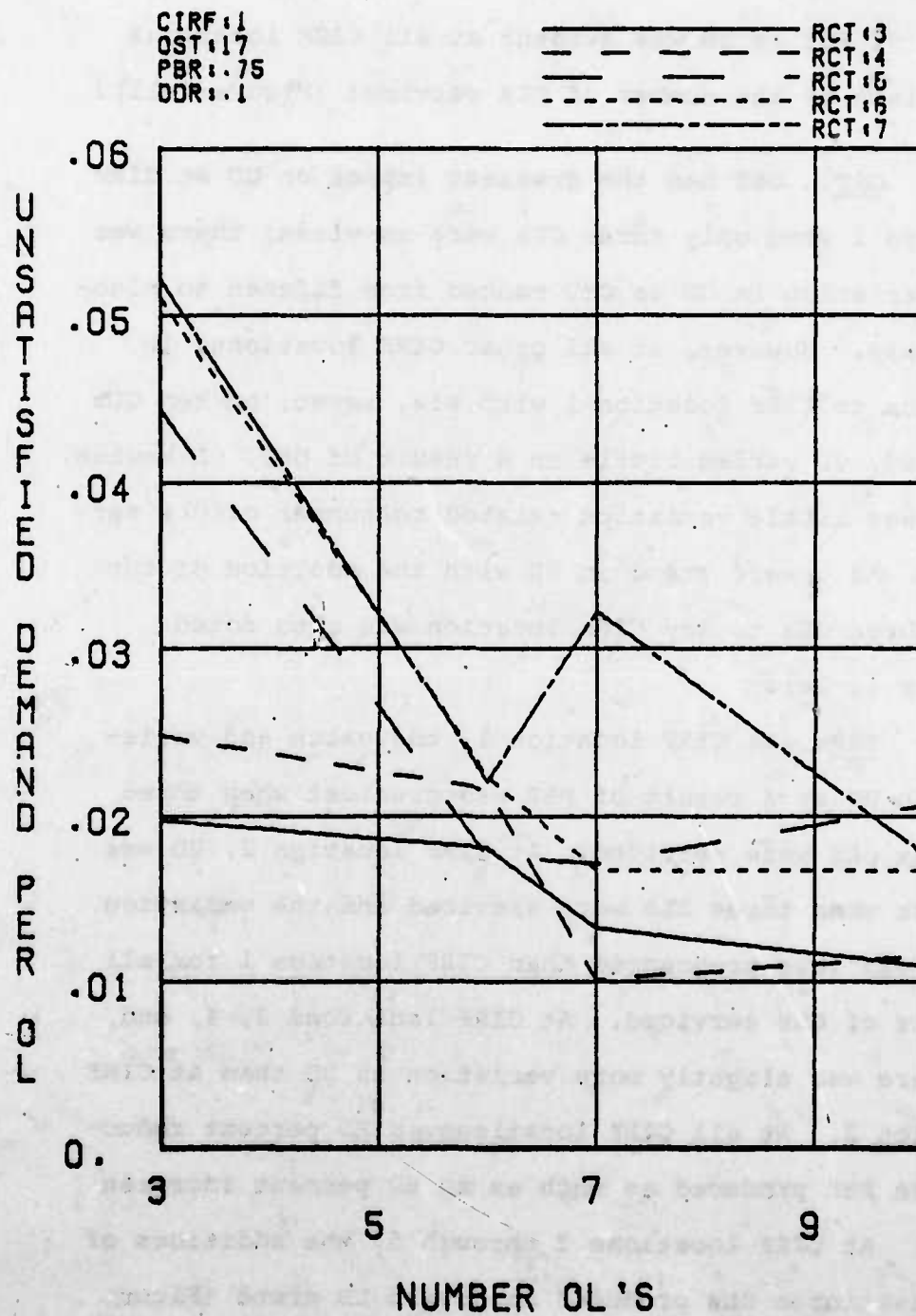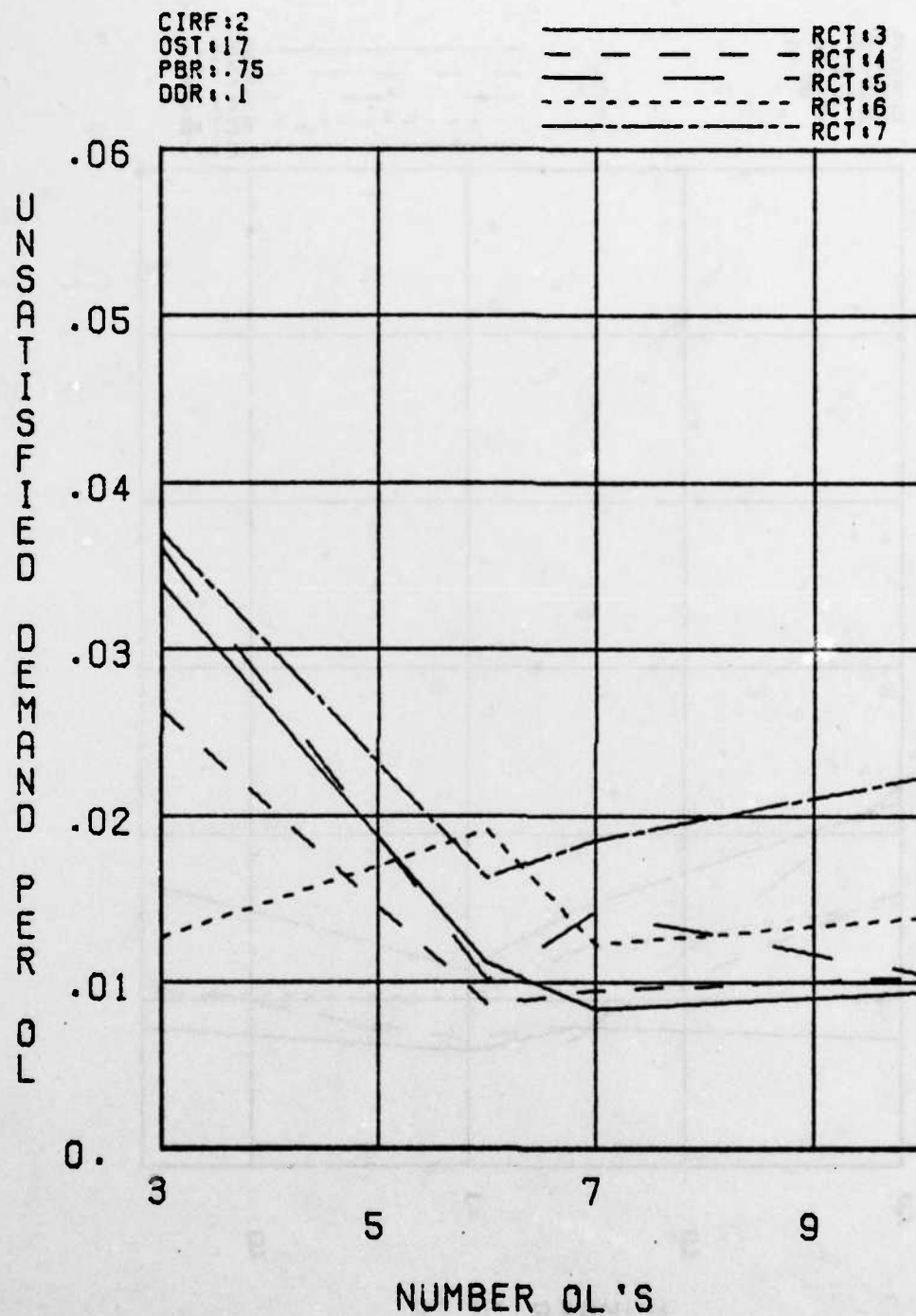
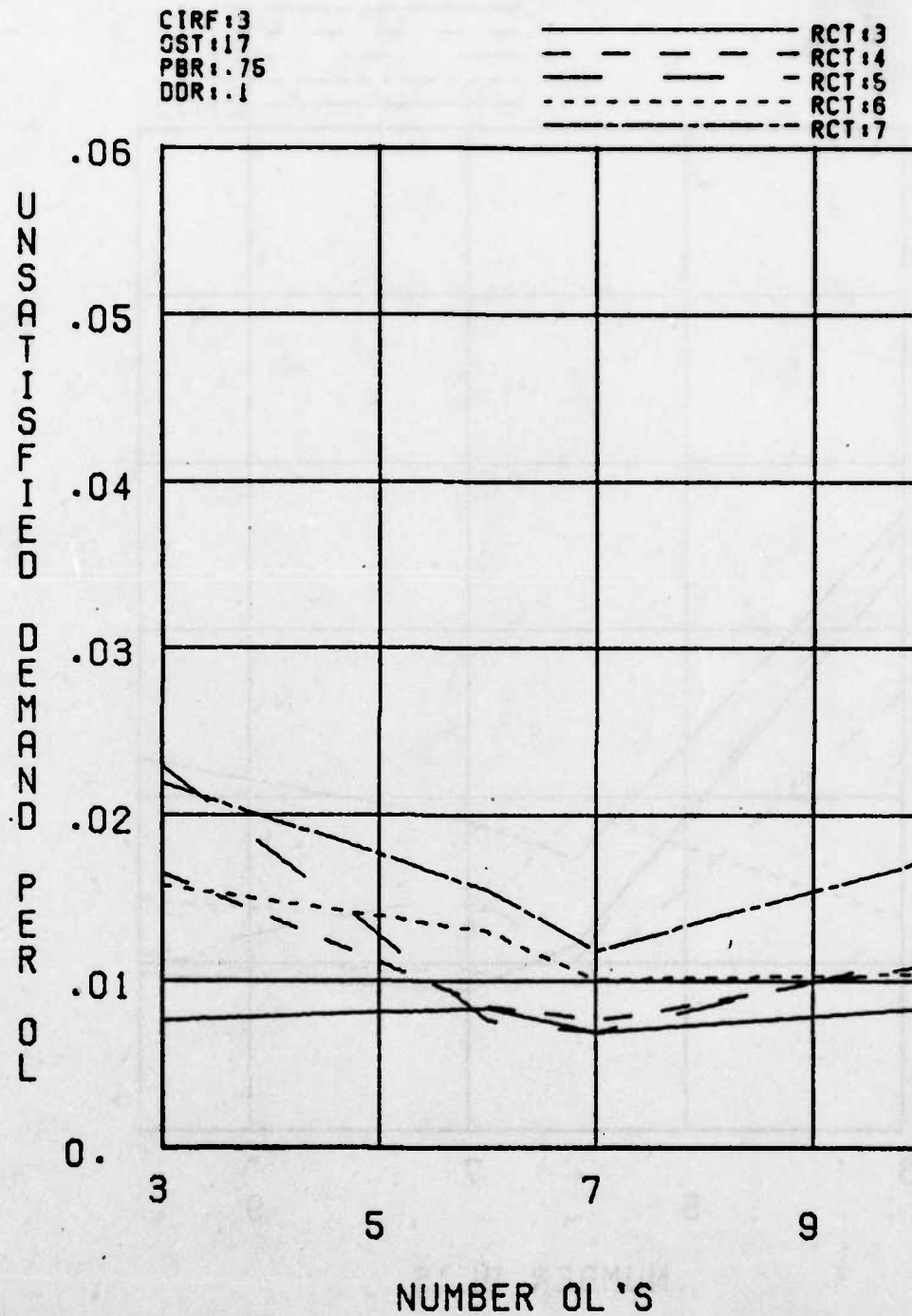FIG. 7. EFFECT OF RCT/CIRF:1

38

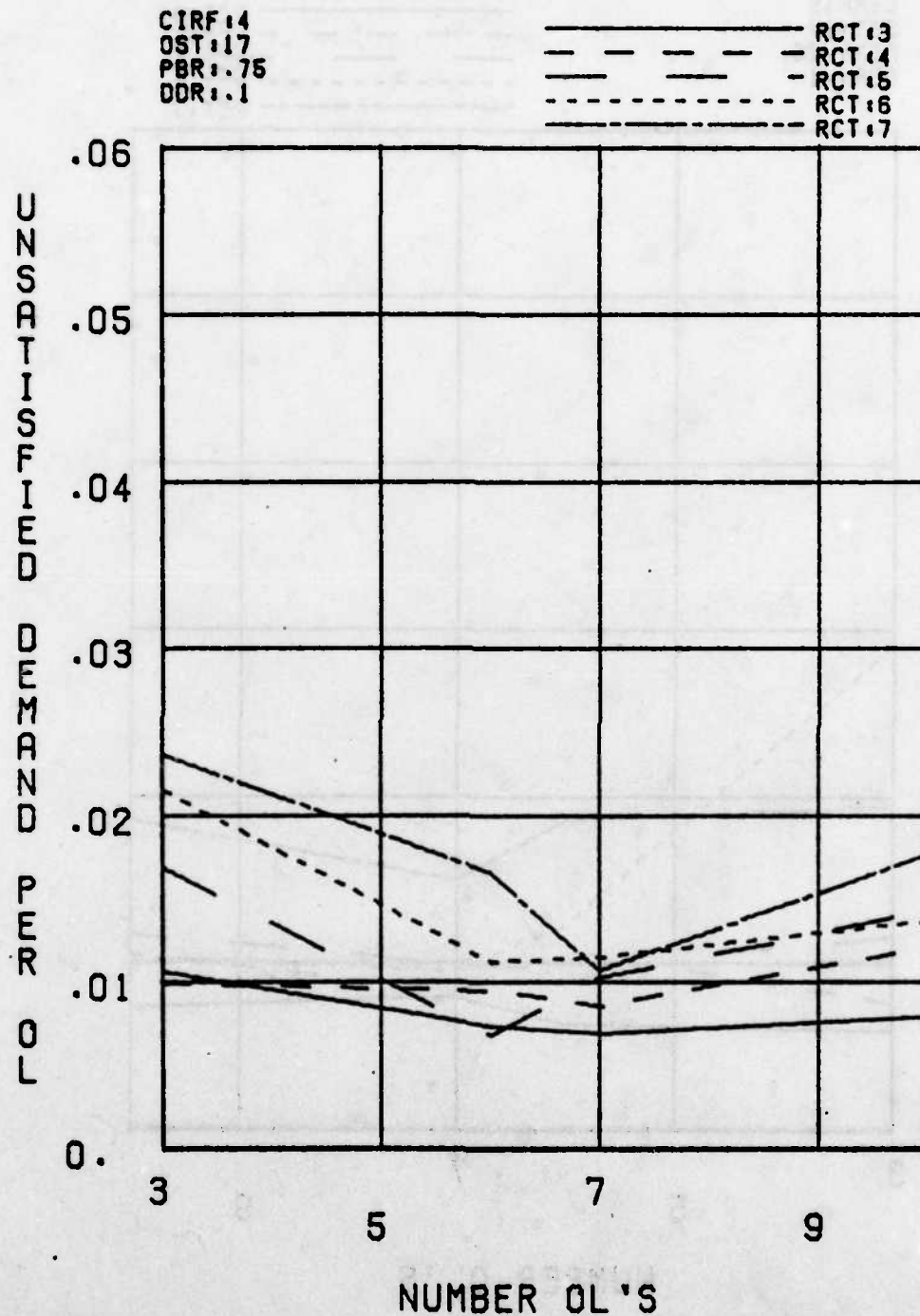FIG. 8. EFFECT OF RCT/CIRF:2

39

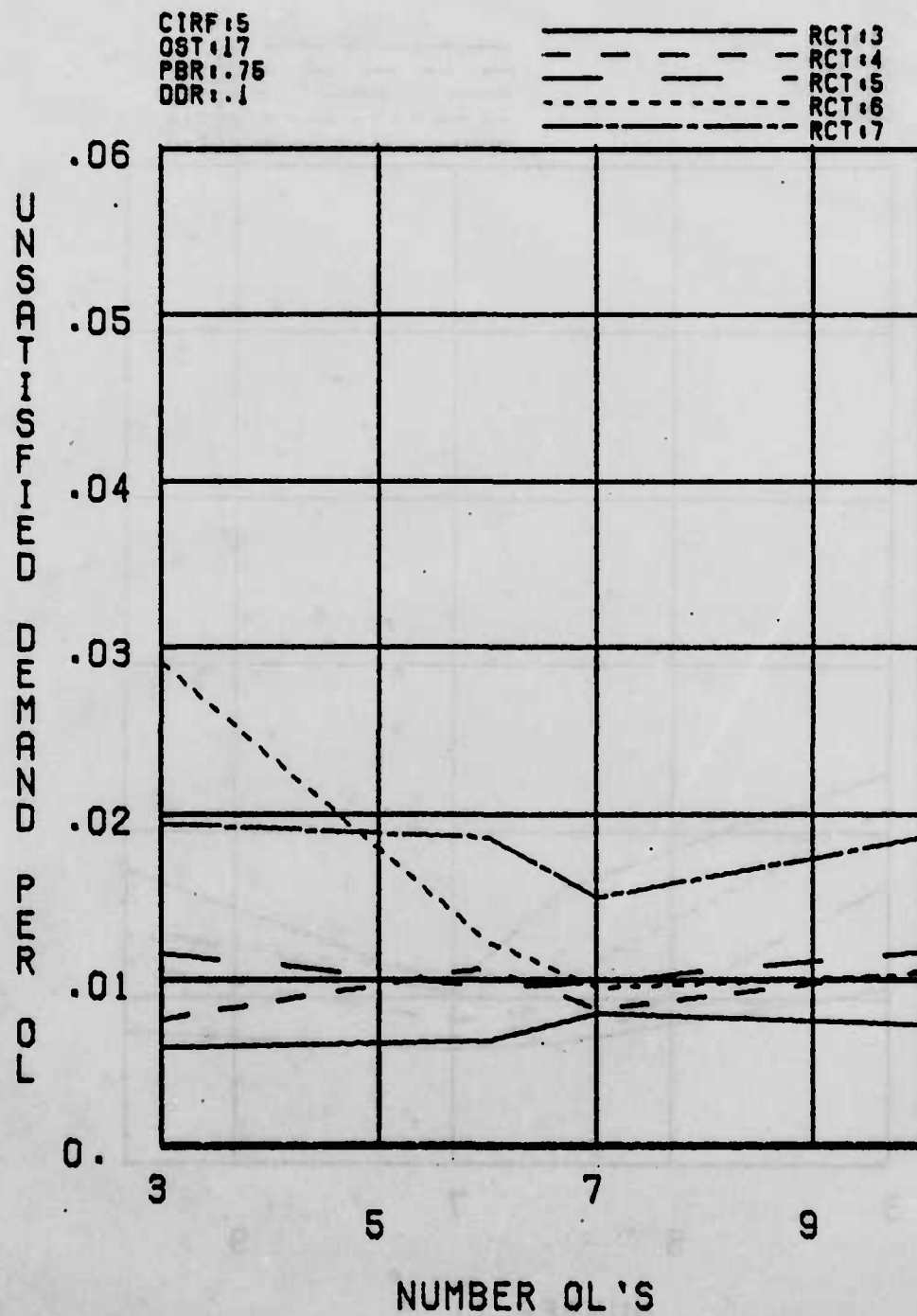FIG. 9. EFFECT OF RCT/CIRF:3

40

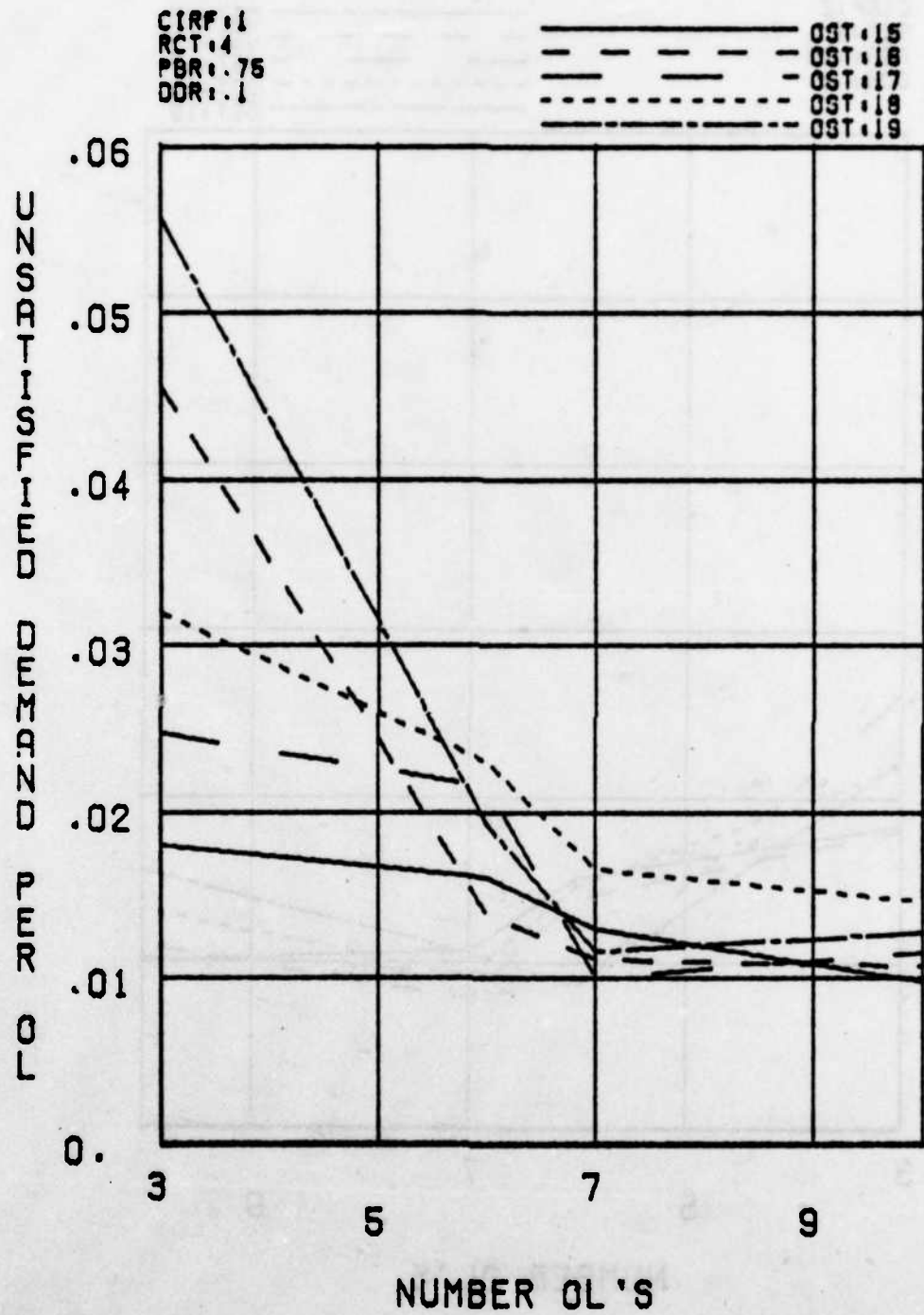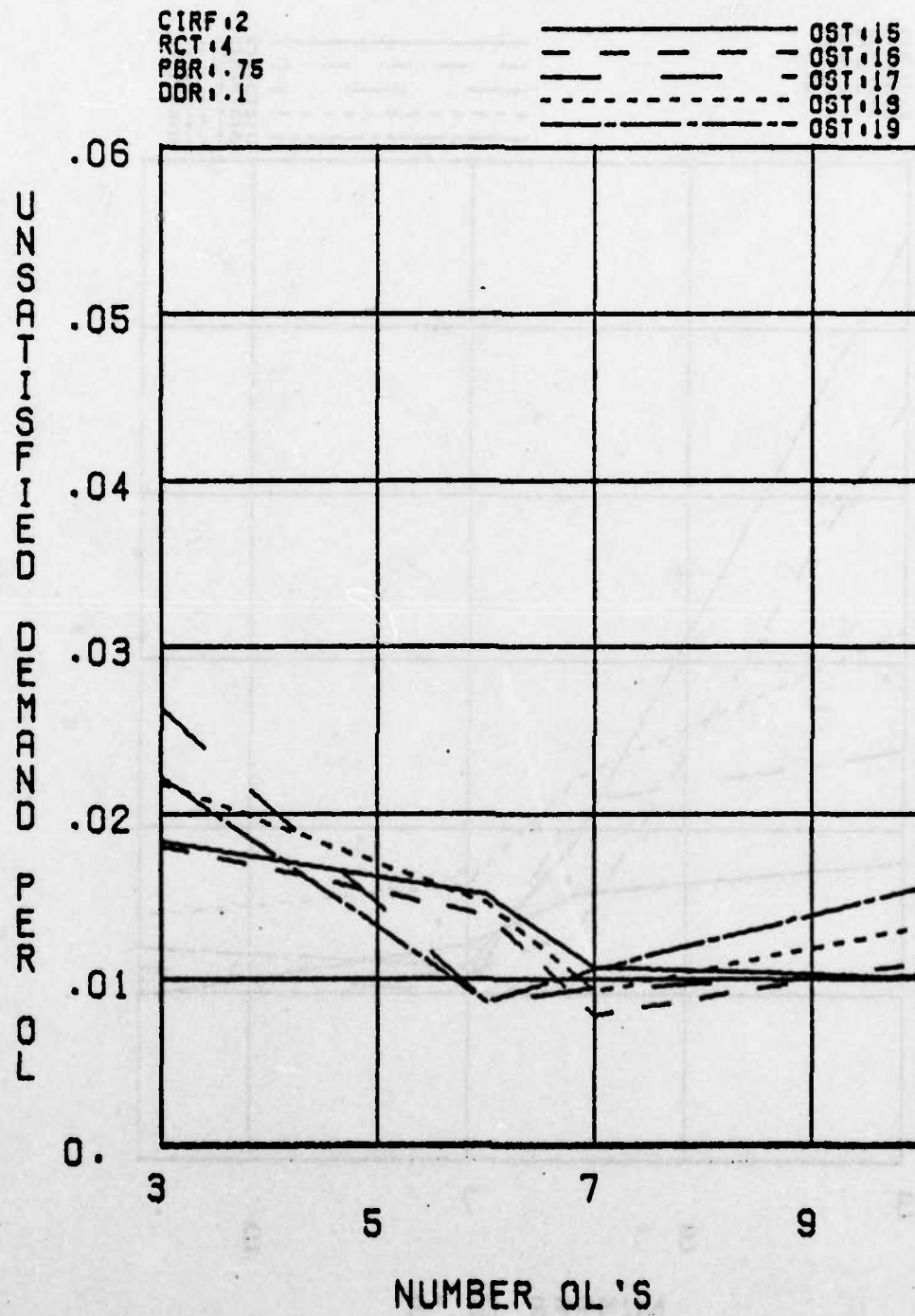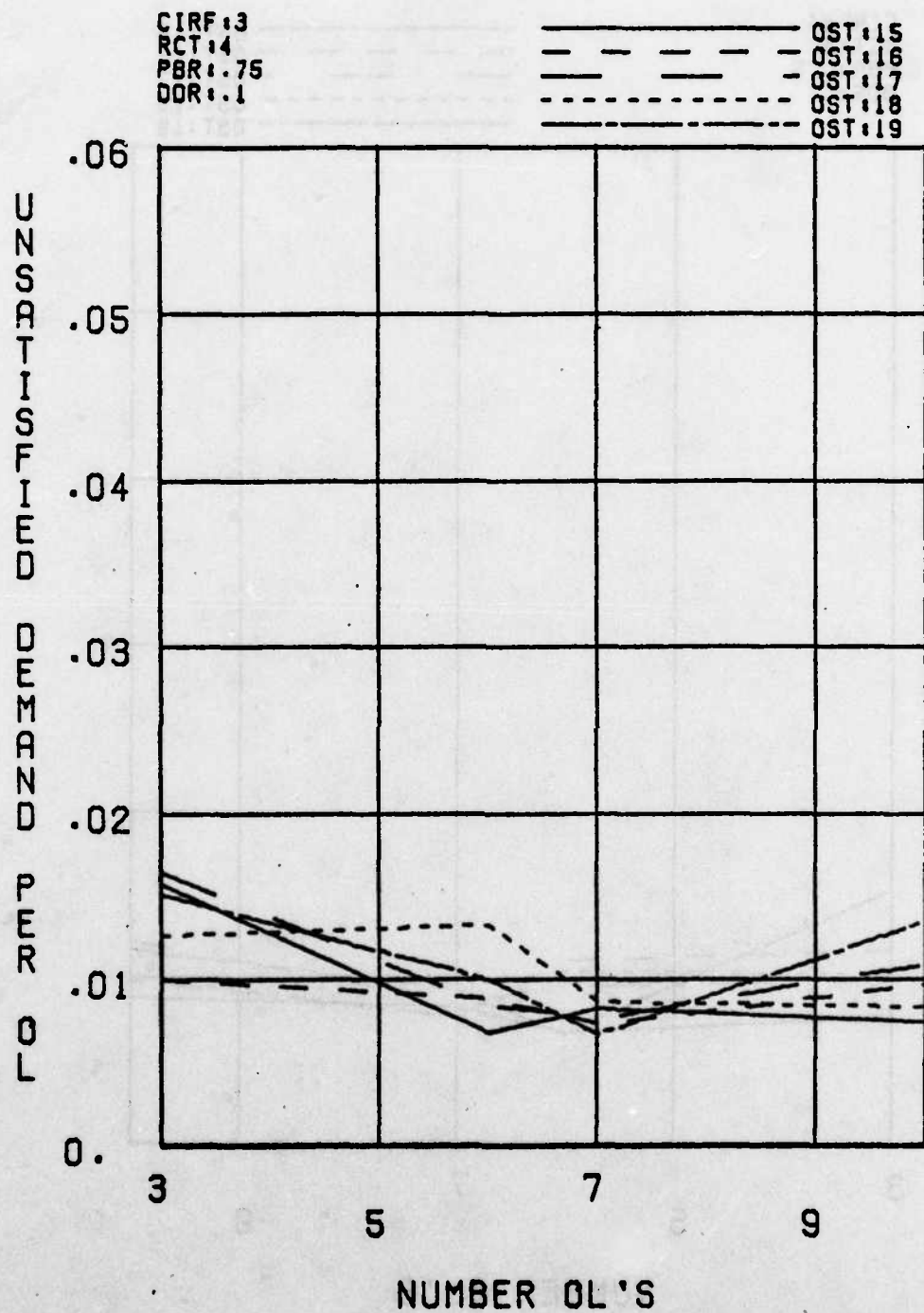FIG. 10. EFFECT OF RCT/CIRF:4

41

FIG. 11. EFFECT OF RCT/CIRF:5

42

CIRF:1
RCT:4
PBR:.75
DDR:.1

OST:15
OST:16
OST:17
OST:18
OST:19

UNSATISFIED DEMAND PER OL

NUMBER OL'S

FIG. 12. EFFECT OF OST/CIRF:1

43

FIG. 13. EFFECT OF OST/CIRF:2

44

CIRF:3
RCT:4
PBR:.75
DOR:.1

OST:15
OST:16
OST:17
OST:18
OST:19

UNSATISFIED DEMAND PER OL

NUMBER OL'S

Fig. 14. EFFECT OF OST/CIRF:3

45
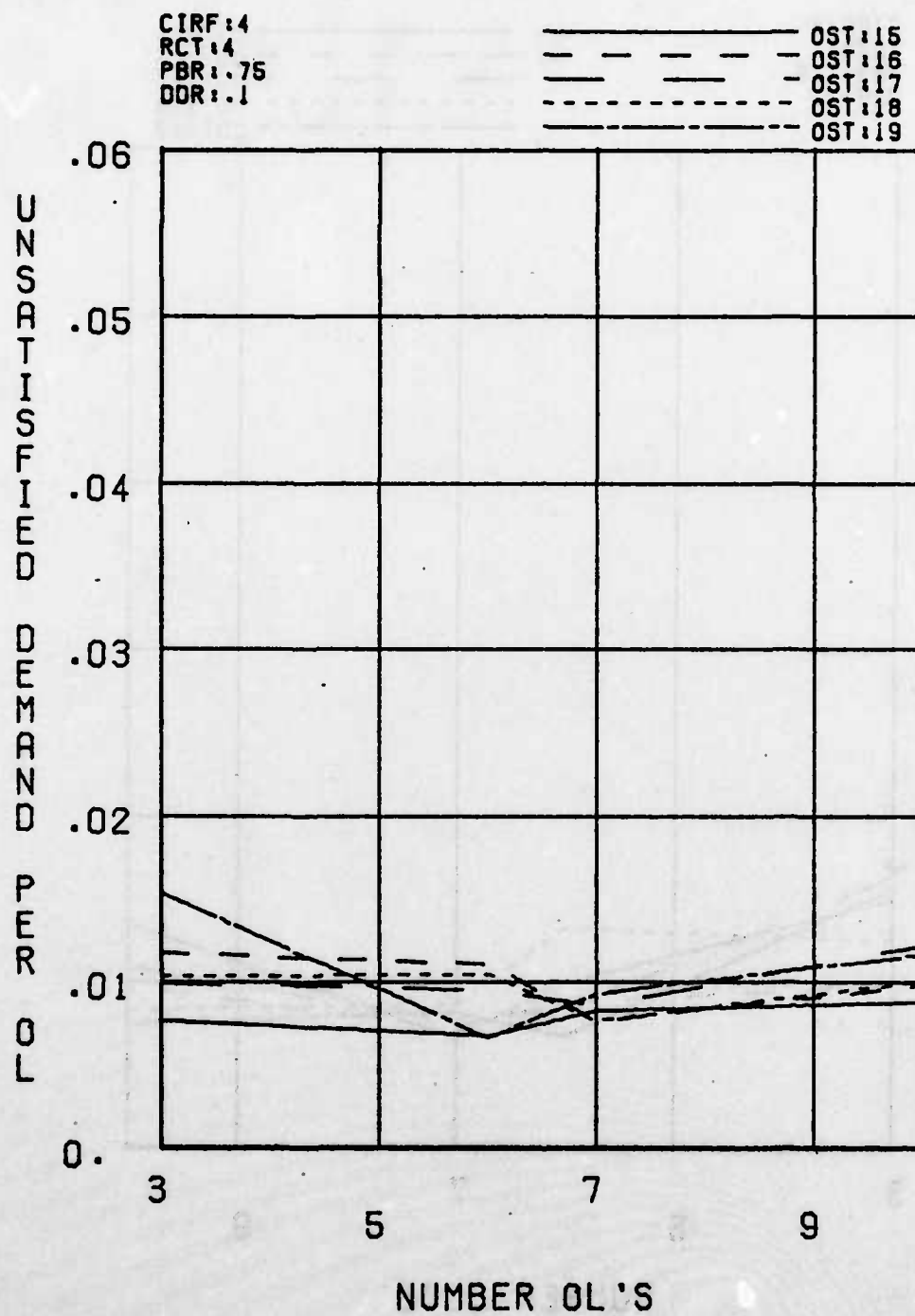
FIG. 15. EFFECT OF OST/CIRF:4

46

CIRF:5
RCT:4
PBR:.75
ODR:.1

OST:15
OST:16
OST:17
OST:18
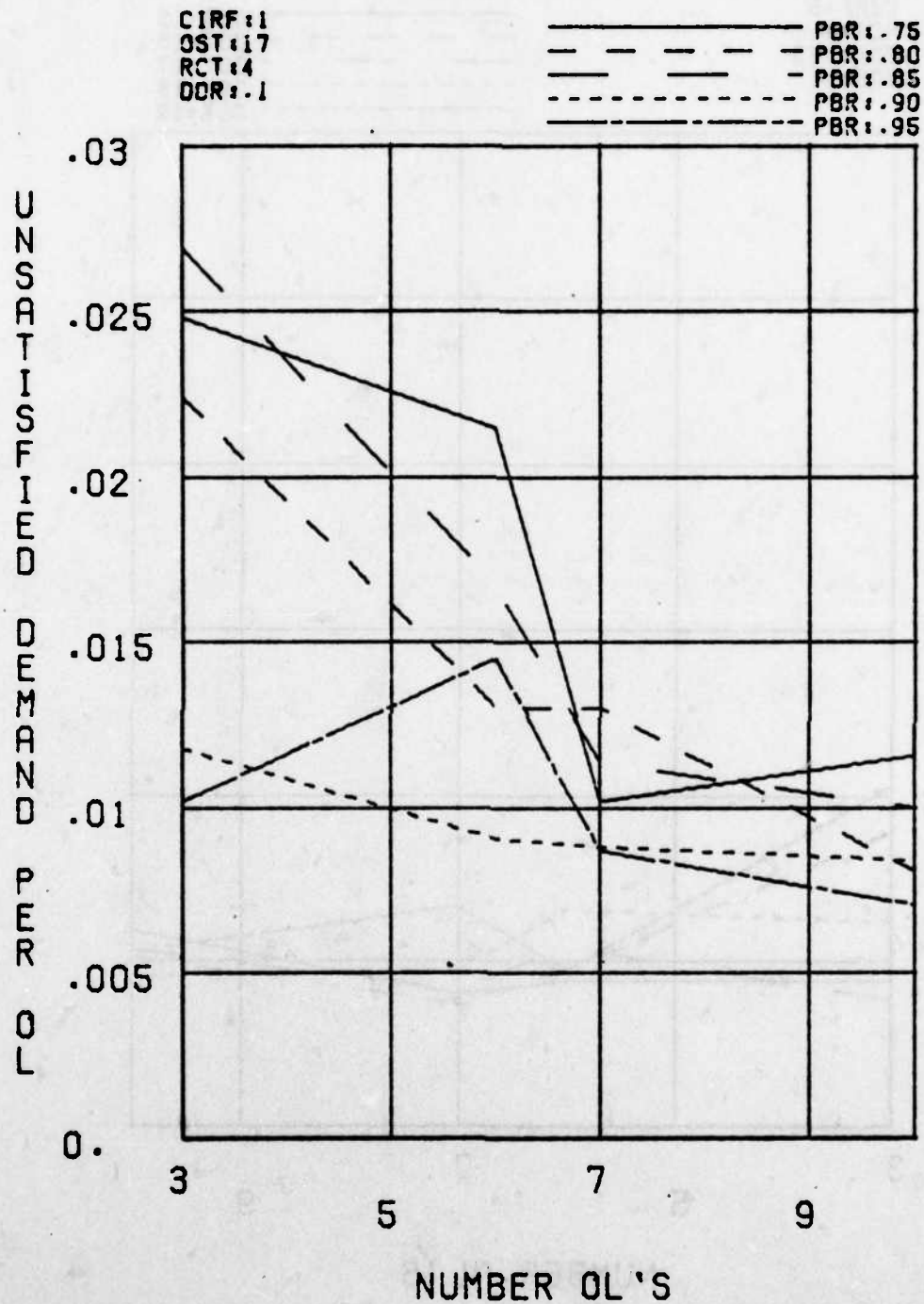OST:19
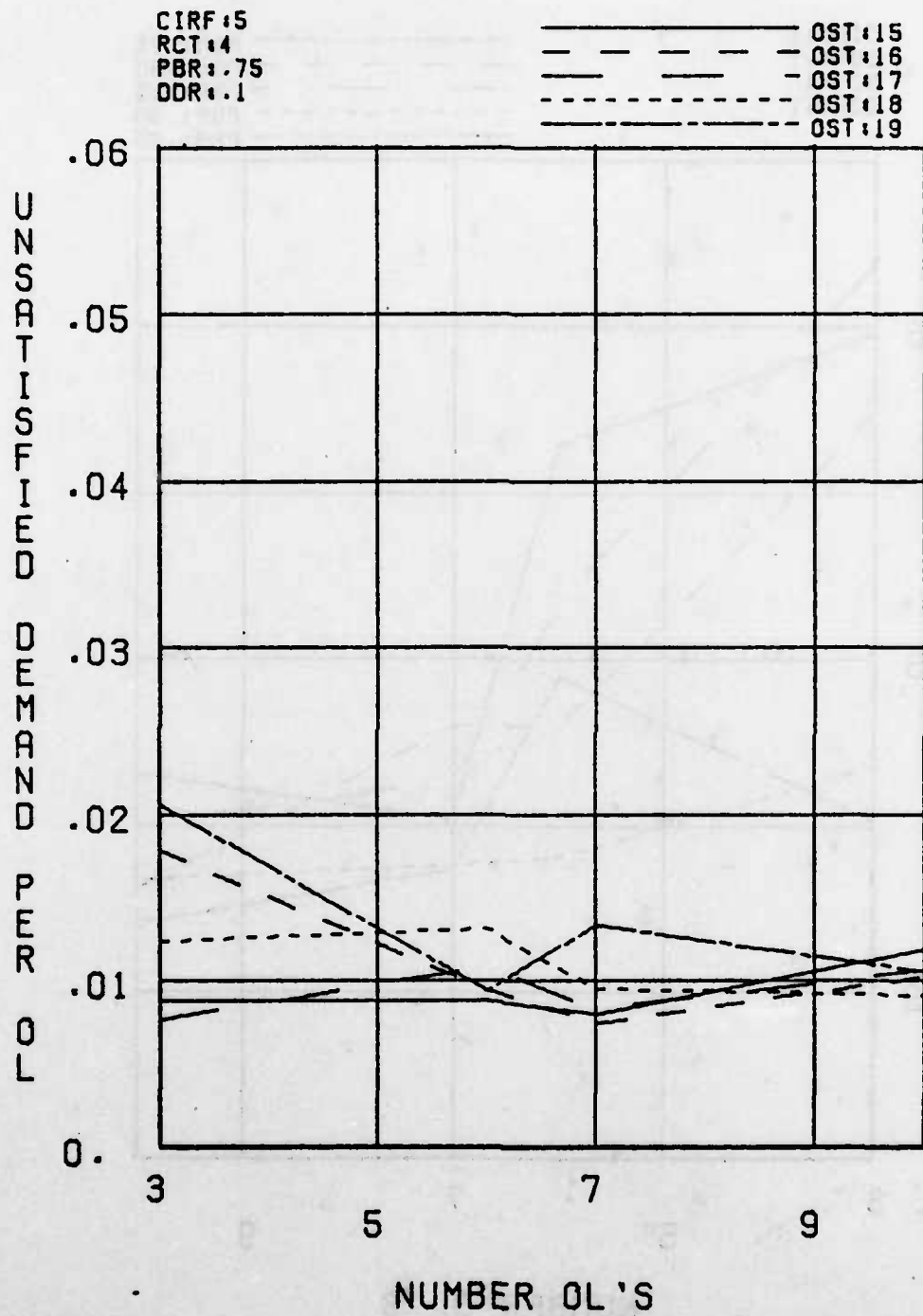
FIG. 16. EFFECT OF OST/CIRF:5
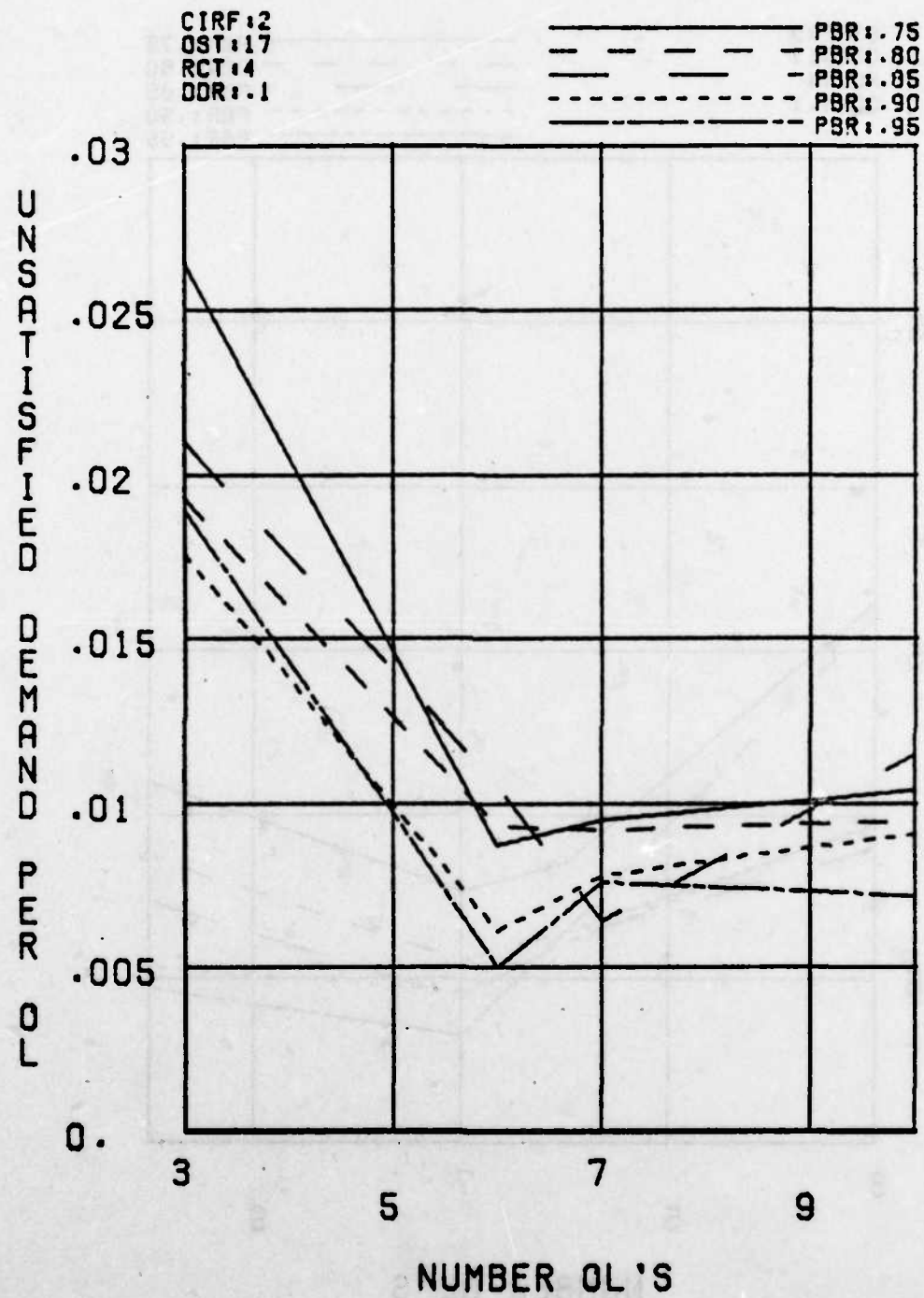
47

FIG. 17. EFFECT OF PBR/CIRF:1
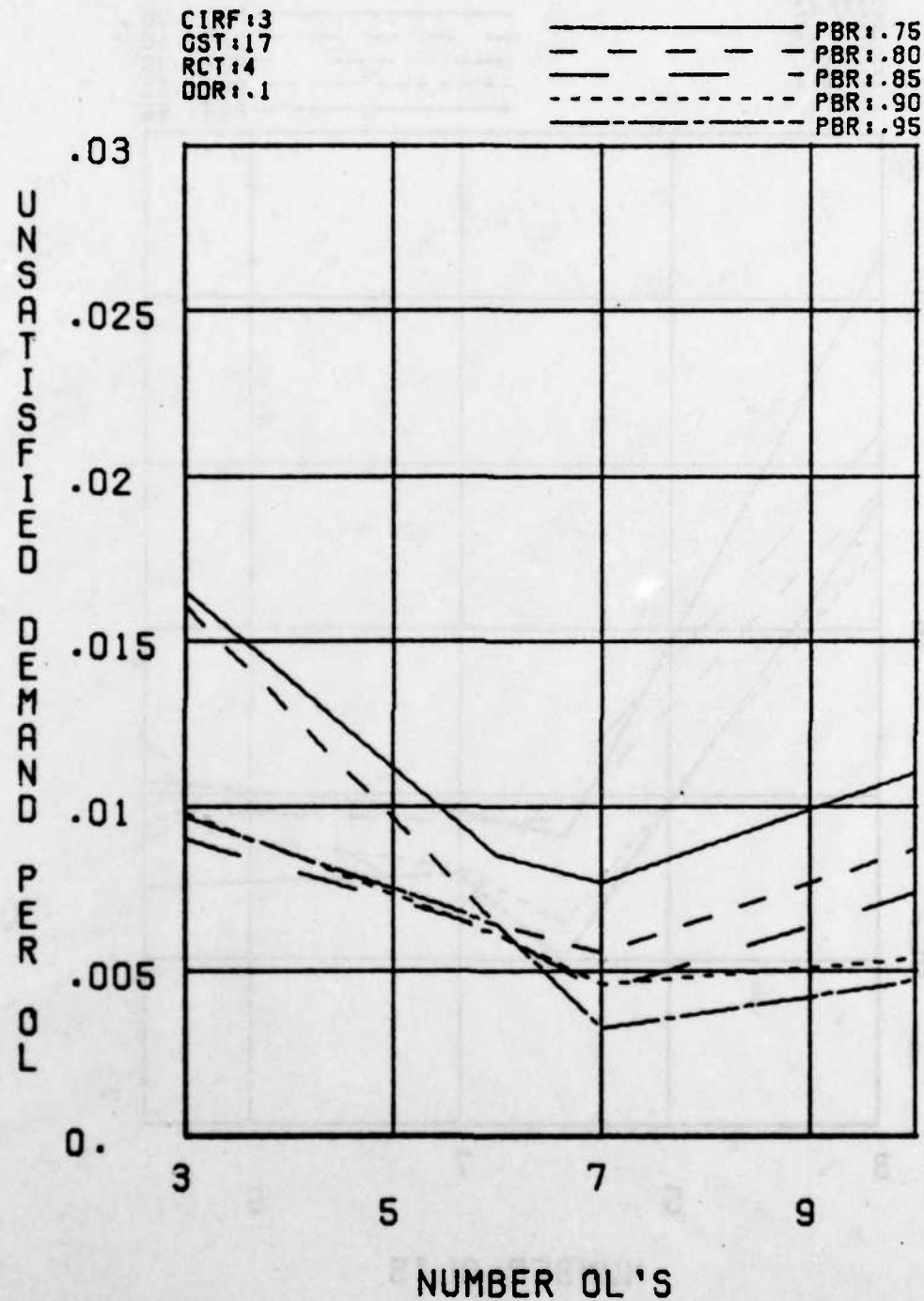
48

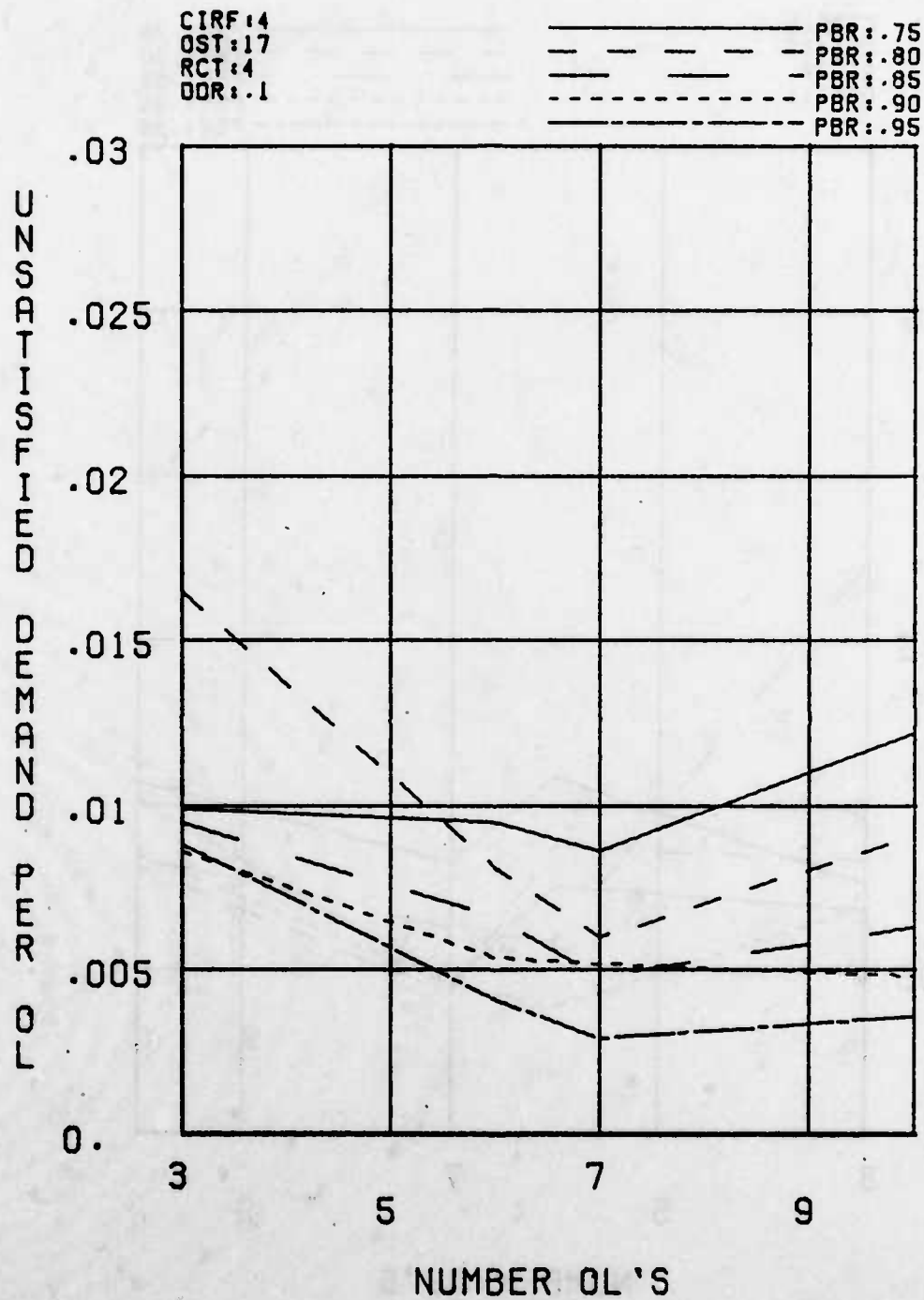FIG. 18. EFFECT OF PBR/CIRF:2

49

FIG. 19. EFFECT OF PBR/CIRF:3

50

FIG. 20. EFFECT OF PBR/CIRF:4

51

CIRF:5
OST:17
RCT:4
DDR:.1

PBR:.75
PBR:.80
PBR:.85
PBR:.90
PBR:.95

UNSATISFIED DEMAND PER OL

.03
.025
.02
.015
.01
.005
0.

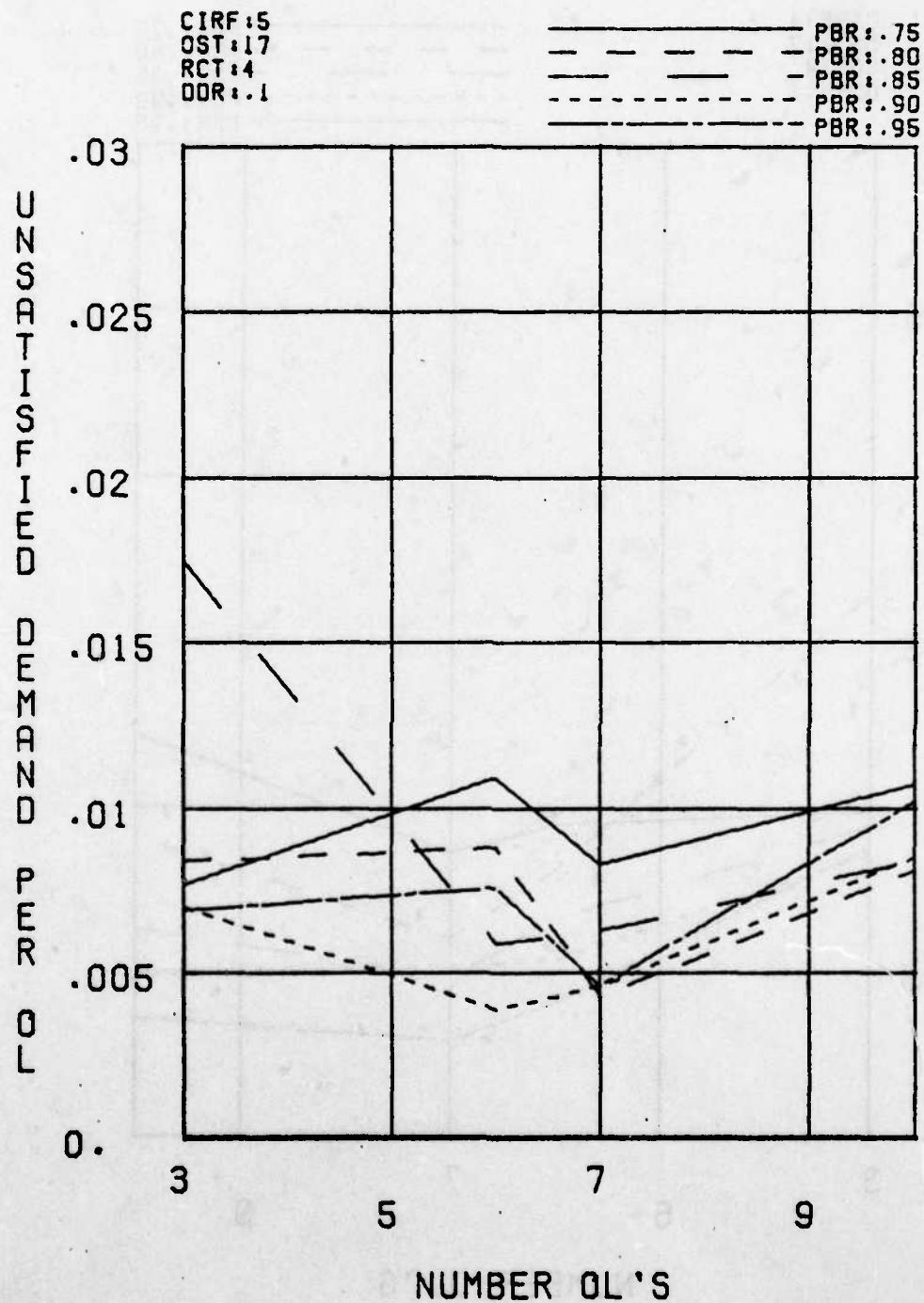3   5   7   9

NUMBER OL'S

Fig. 21. EFFECT OF PBR/CIRF:5

52

DDR. Variations in DDR produced the greatest changes in UD. Because of extremely low UDs, a DDR of .05 demands per day produced no trace on the graphs. CIRF location 1 produced the greatest UD variation as a result of increased DDR. The higher DDRs produced progressively more variation. At CIRF locations 2 through 5, DDRs of .10 and .15 demands per day produced approximately the same UD values regardless of the number of OLs serviced. DDRs of .20 and .25 demands per day produced UDs which varied more with number of OLs serviced. There was an overall trend toward lower UDs as the number of OLs serviced increased except for the addition of the last three OLs at CIRF locations 2 through 5 where an upward trend occurred (Figure 22-26).

Impact of CIRF location on UD

RCT. RCT was ranged from three to seven days with other variables set at baseline values. With an RCT of three days and three OLs being serviced, there was considerable variation in UD between CIRF locations. As OLs were added, this variation was steadily reduced. At an RCT of four days, there was considerable variation again between CIRF locations with three OLs serviced. With six OLs being serviced only
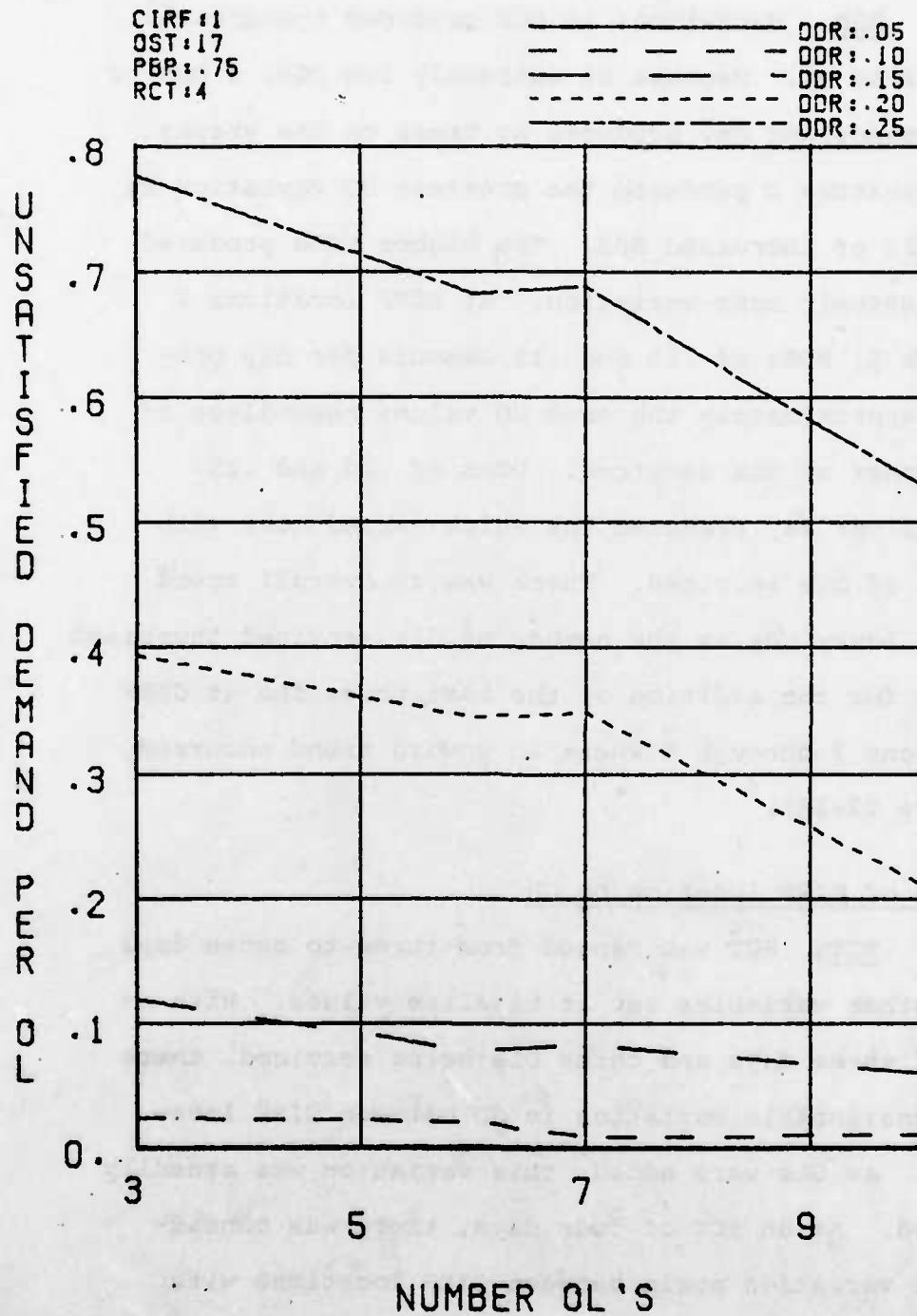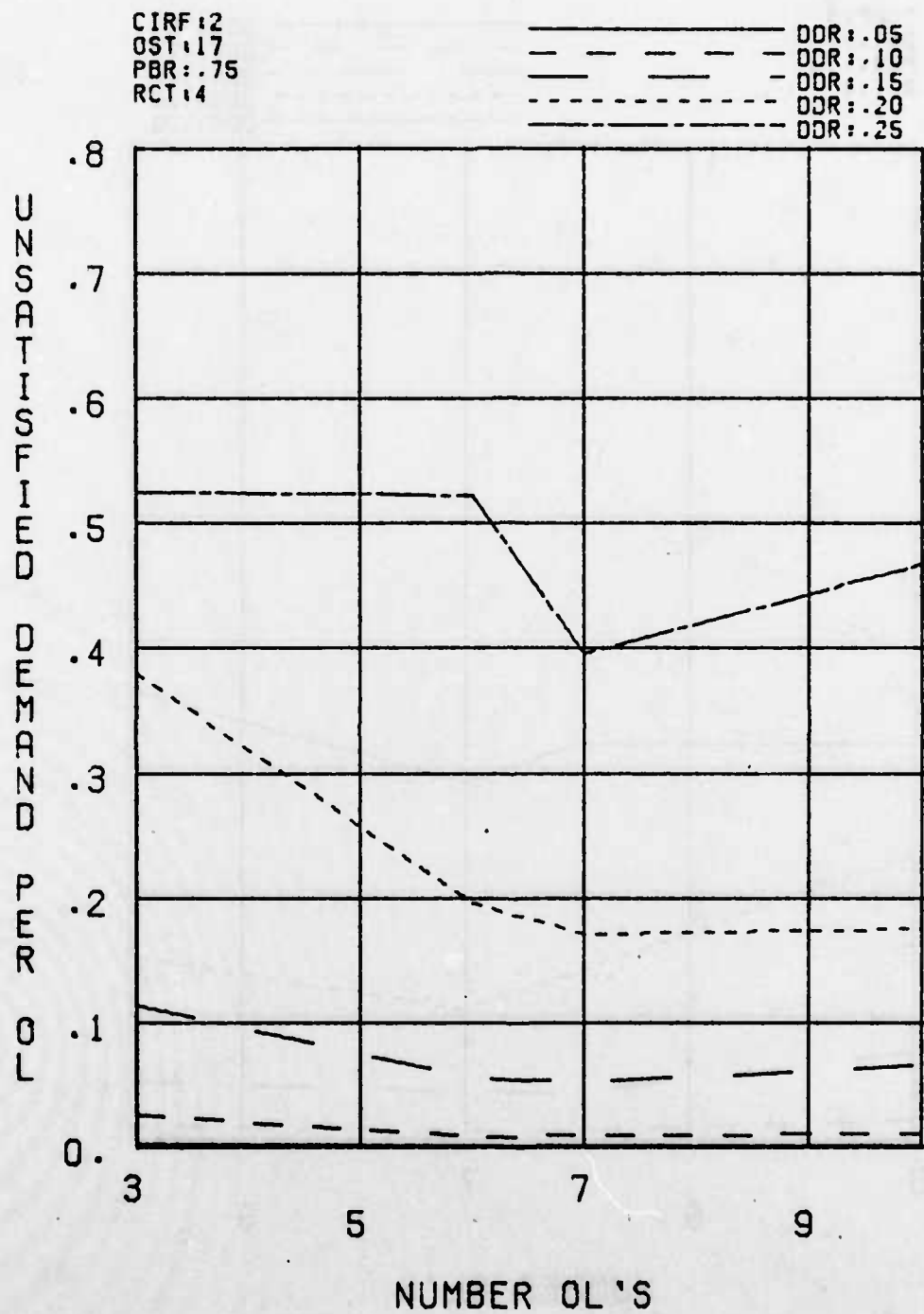
53

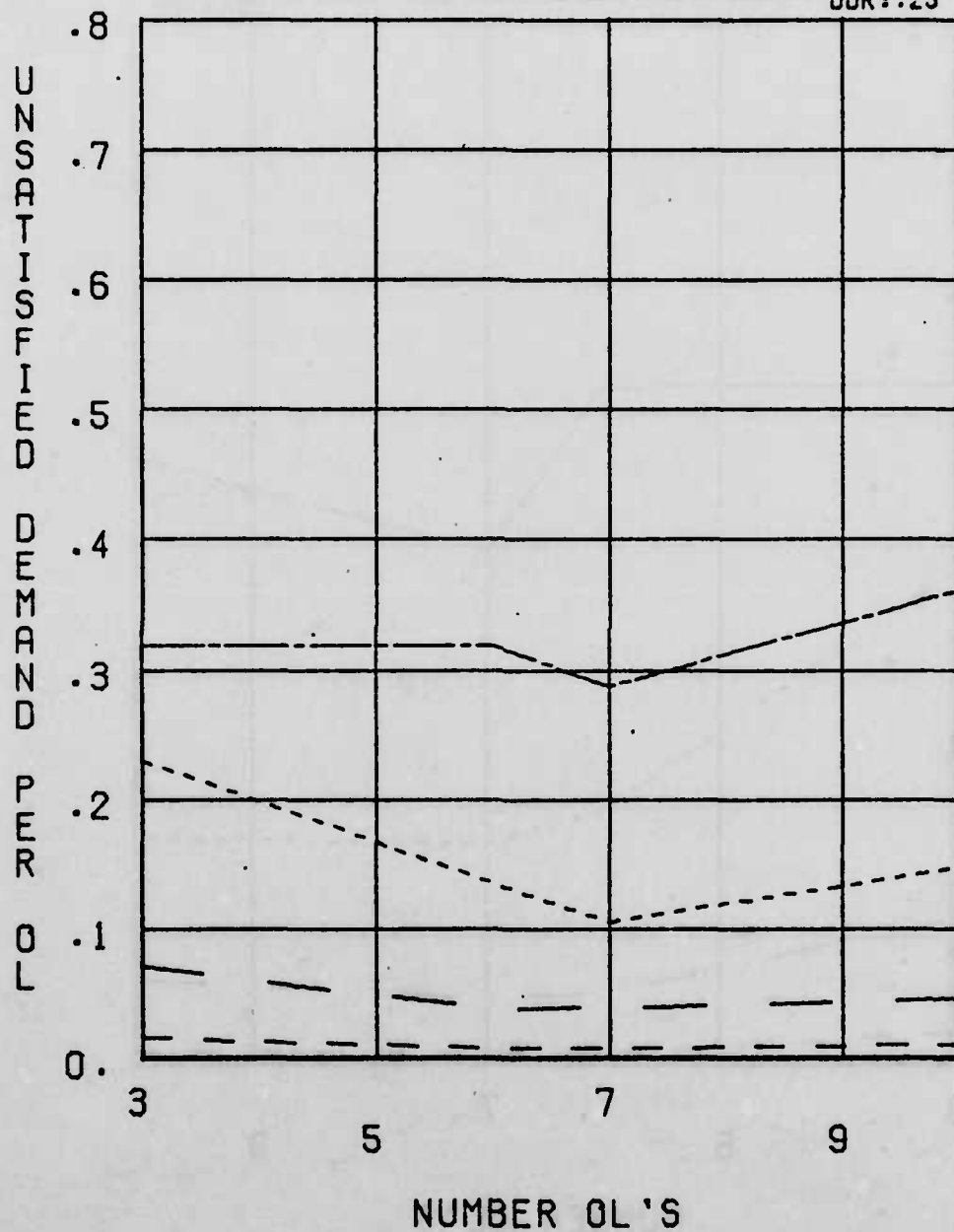FIG. 22. EFFECT OF DDR/CIRF:1

54

FIG. 23. EFFECT OF DDR/CIRF:2

55
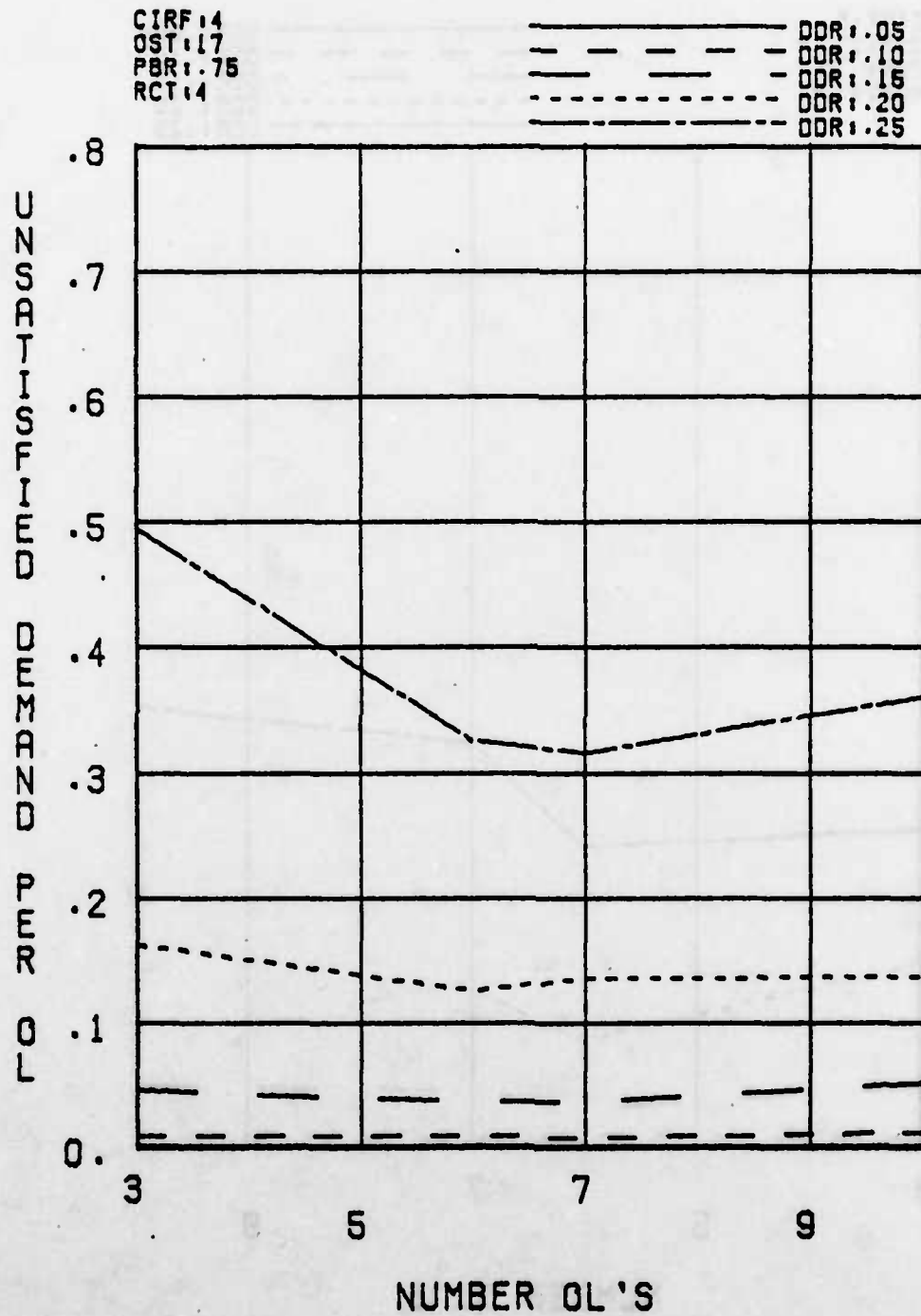
FIG. 24. EFFECT OF DDR/CIRF:3
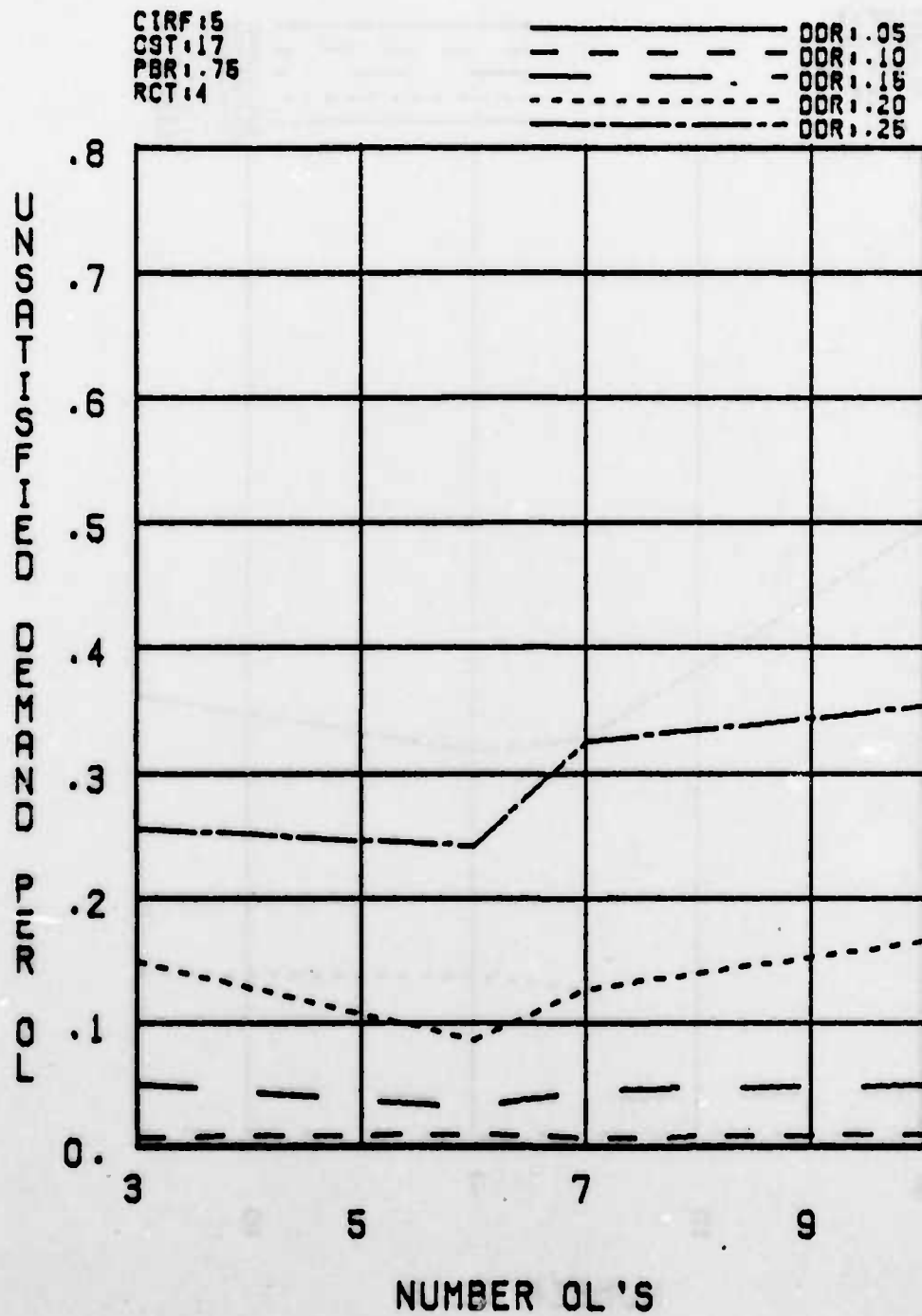
FIG. 25. EFFECT OF DDR/CIRF:4

57

FIG. 26. EFFECT OF DDR/CIRF:5

CIRF location 1 varied noticeably from the other loca-
tions. With seven and ten OLs being serviced there was
little variation between locations. There was little
change in the magnitude of UD between RCT of three and
four days. As RCT was increased to five through seven
days, UDs increased slightly and the variation between
locations became more pronounced. The addition of the
last three OLs produced a slight upward trend at CIRF
locations 2 through 5 and at CIRF location 1 when RCT
was six days or less. CIRF location 5 also produced
more stable UDs than CIRF locations 1 and 2 (Figure
27-31).

OST. When OST was set at fifteen days, with
RCT, PBR, and DDR set at the baseline values, there
was decreasing variation in UD as the number of OLs
serviced increased. As OST was increased from sixteen
to nineteen days, the same general trend was observed
with UD increasing only slightly as OST increased.
Generally, the more OLs serviced, the lower the observed
UD regardless of the values of OST or the CIRF loca-
tion. The exception to this observation was in the
addition of the last three OLs to CIRF locations 2
through 5 where there was a slight upward trend in UD.
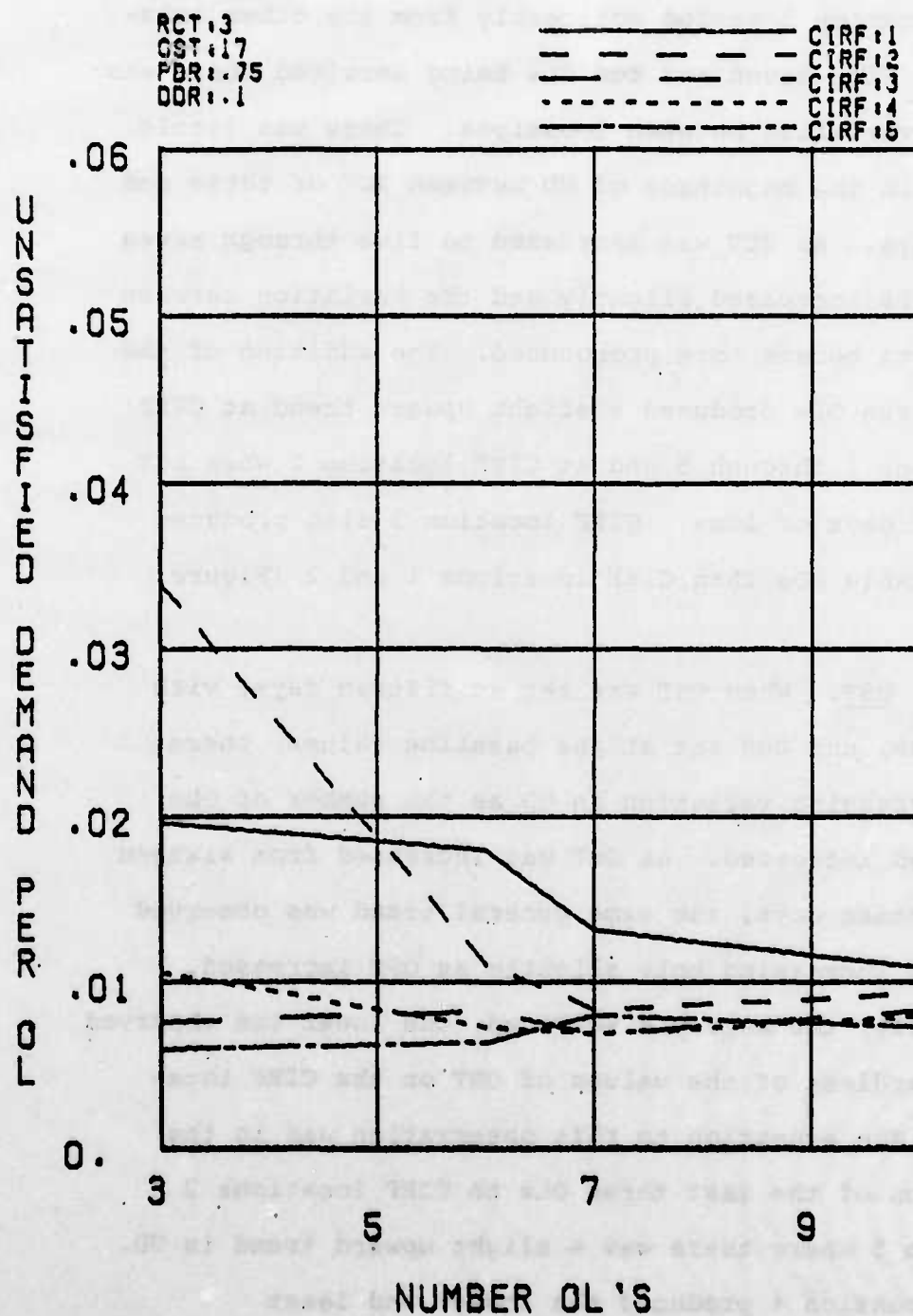CIRF location 4 produced the lowest and least

59

FIG. 27. CIRF LOCATION EFFECT/RCT:3
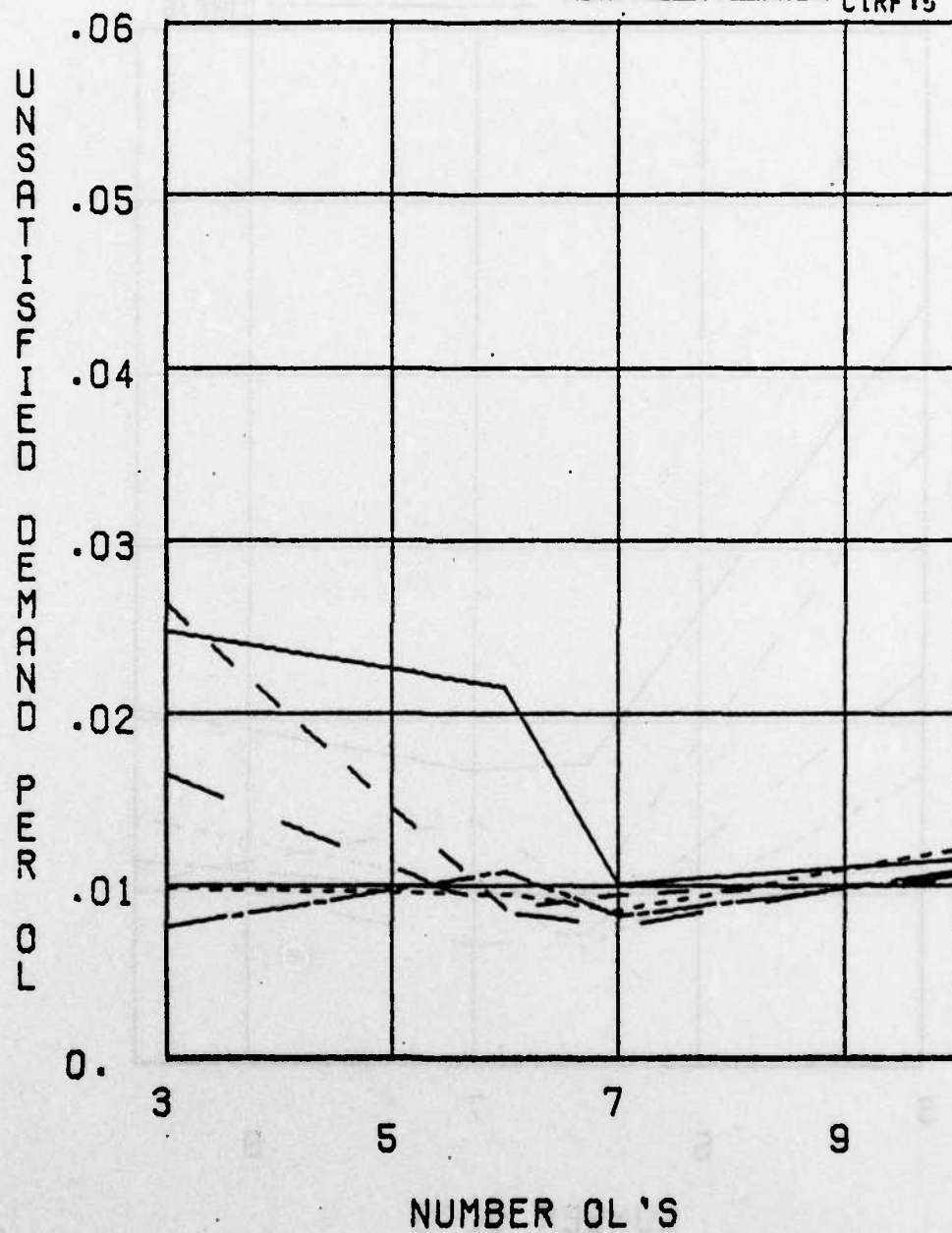
Fɪɢ. 28. CIRF LOCATION EFFECT/RCT:4

61

FIG. 29. CIRF LOCATION EFFECT/RCT:5

FIG. 30. CIRF LOCATION EFFECT/RCT:6

63
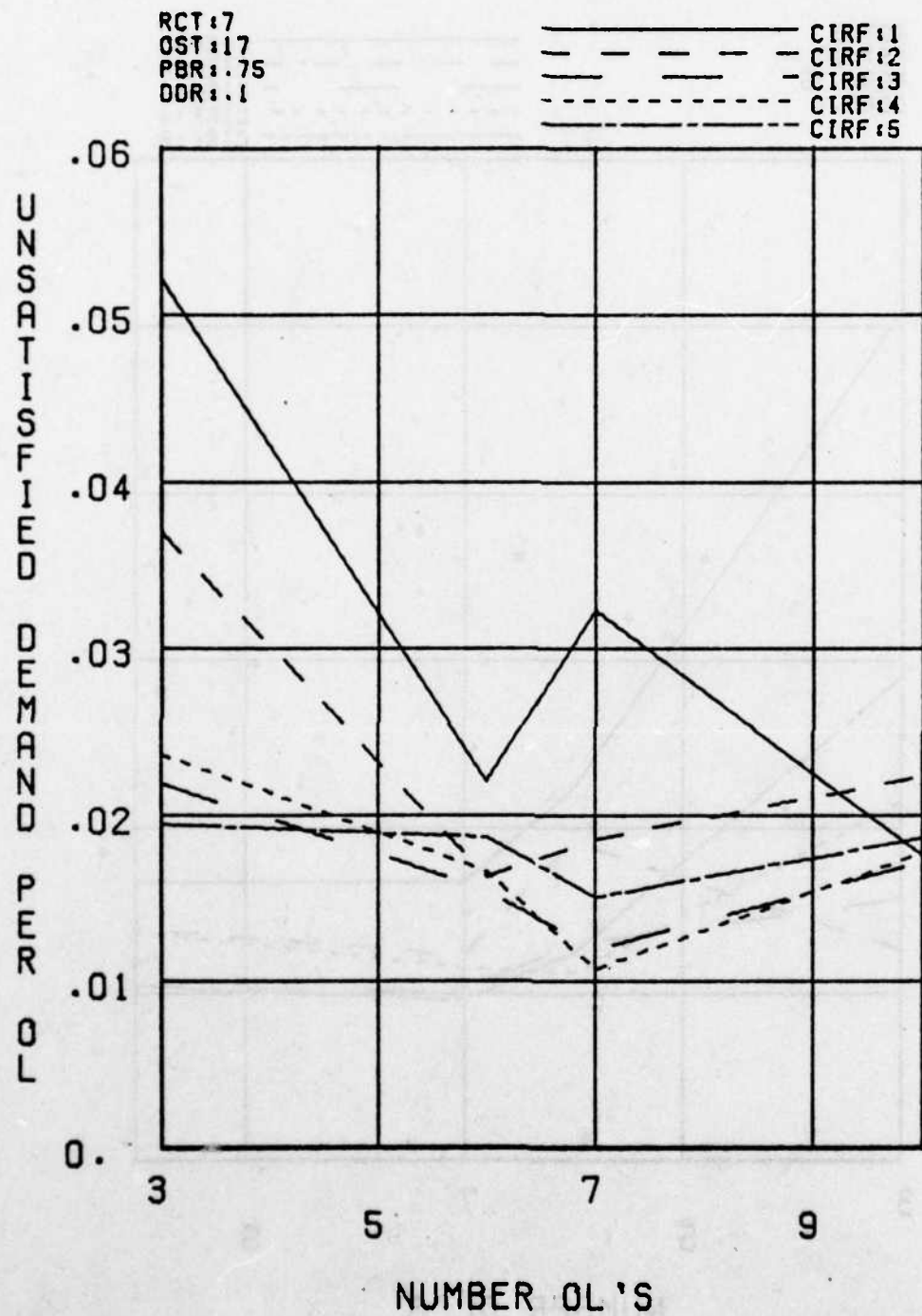
Fig. 31. CIRF LOCATION EFFECT/RCT:7

variable values of UD followed by CIRF locations 3,
5, and 2. CIRF location 1 generally produced the
highest UDS (Figure 32-36).

PBR. With PBR set at 75 percent and the
baseline values assigned to OST, RCT, and DDR, there
was a wide variation in UD due to CIRF location.
Generally, greater variation was observed when three
and six OLs were serviced. A downward trend in UD
was observed as the number of OLs serviced increased
from three through seven, however, all locations
experienced a slight increase with the addition of
the last three OLs (Figure 37-41).

As PBR was increased from 80 to 95 percent,
there was generally similar variation in UD between
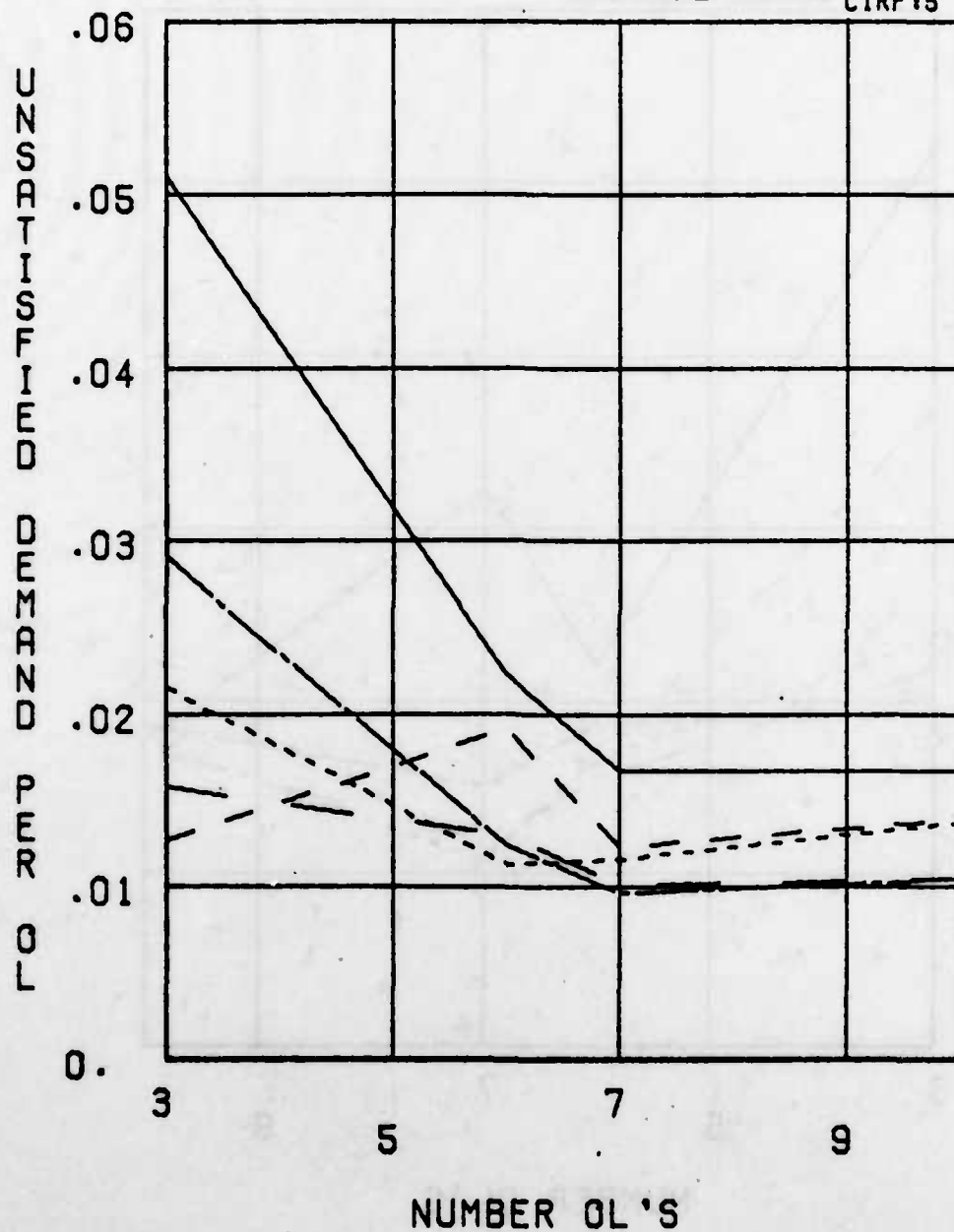locations. As PBR grew, variation between CIRF loca-
tion became increasingly erratic. All locations showed
a slight downward trend in UD as a result of servicing
additional OLs. However, the addition of the last
three OLs produced a slightly higher UD. CIRF loca-
tion 3 produced the least variable and lowest UDs fol-
lowed by CIRF locations 4, 5, 2, and 1.

DDR. When DDR was set at .05 demands per day
and OST, PBR, and RCT set at their baseline values, the
results were graphed on an expanded scale to show the
extremely small resultant UDs. There was little

65

CST:15
RCT:4
PBR:.75
DDR:.1

CIRF:1
CIRF:2
CIRF:3
CIRF:4
CIRF:5

UNSATISFIED DEMAND PER OL

.06
.05
.04
.03
.02
.01
0.

3   5   7   9

NUMBER OL'S

FIG. 32. CIRF LOCATION EFFECT/OST:15
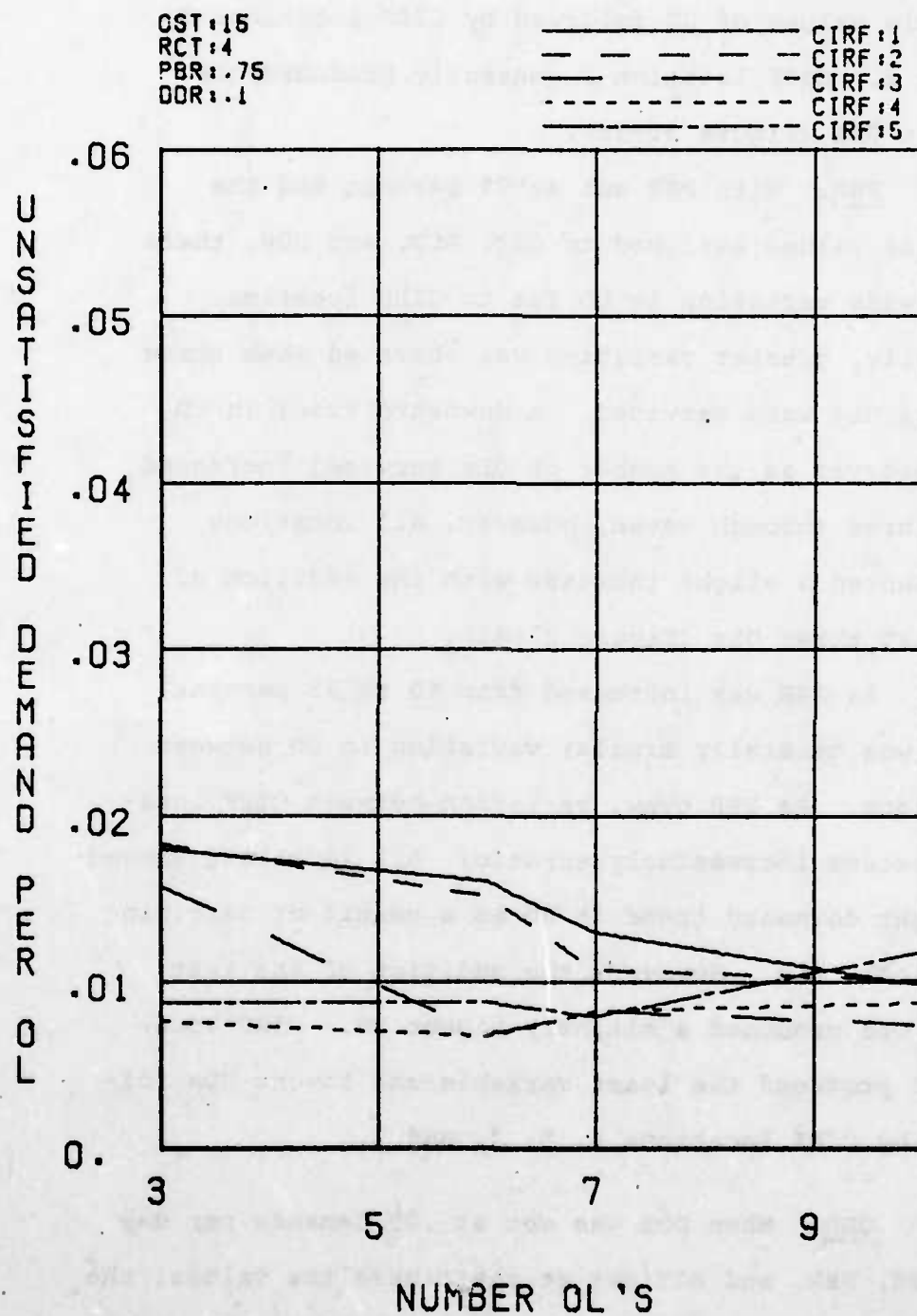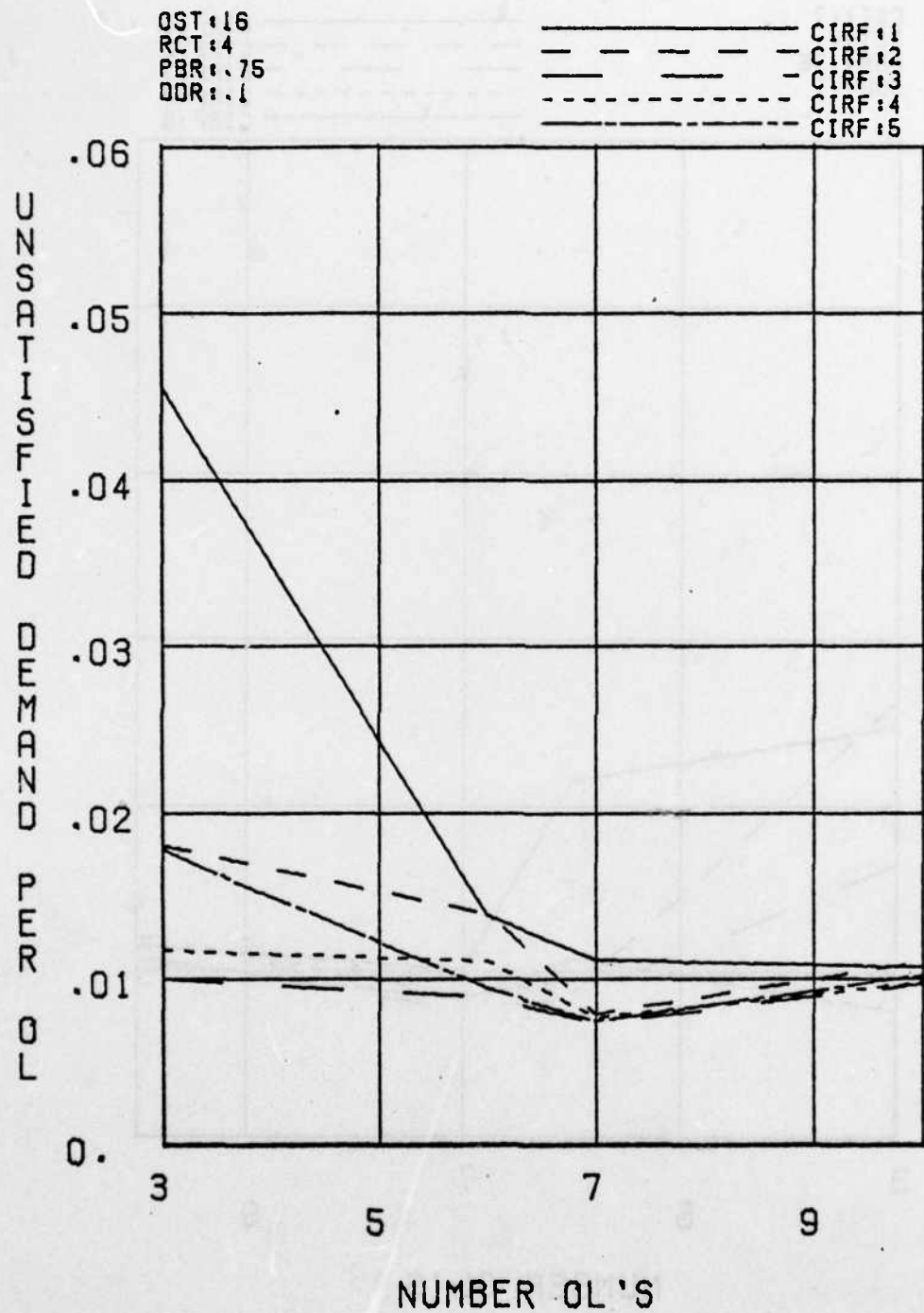
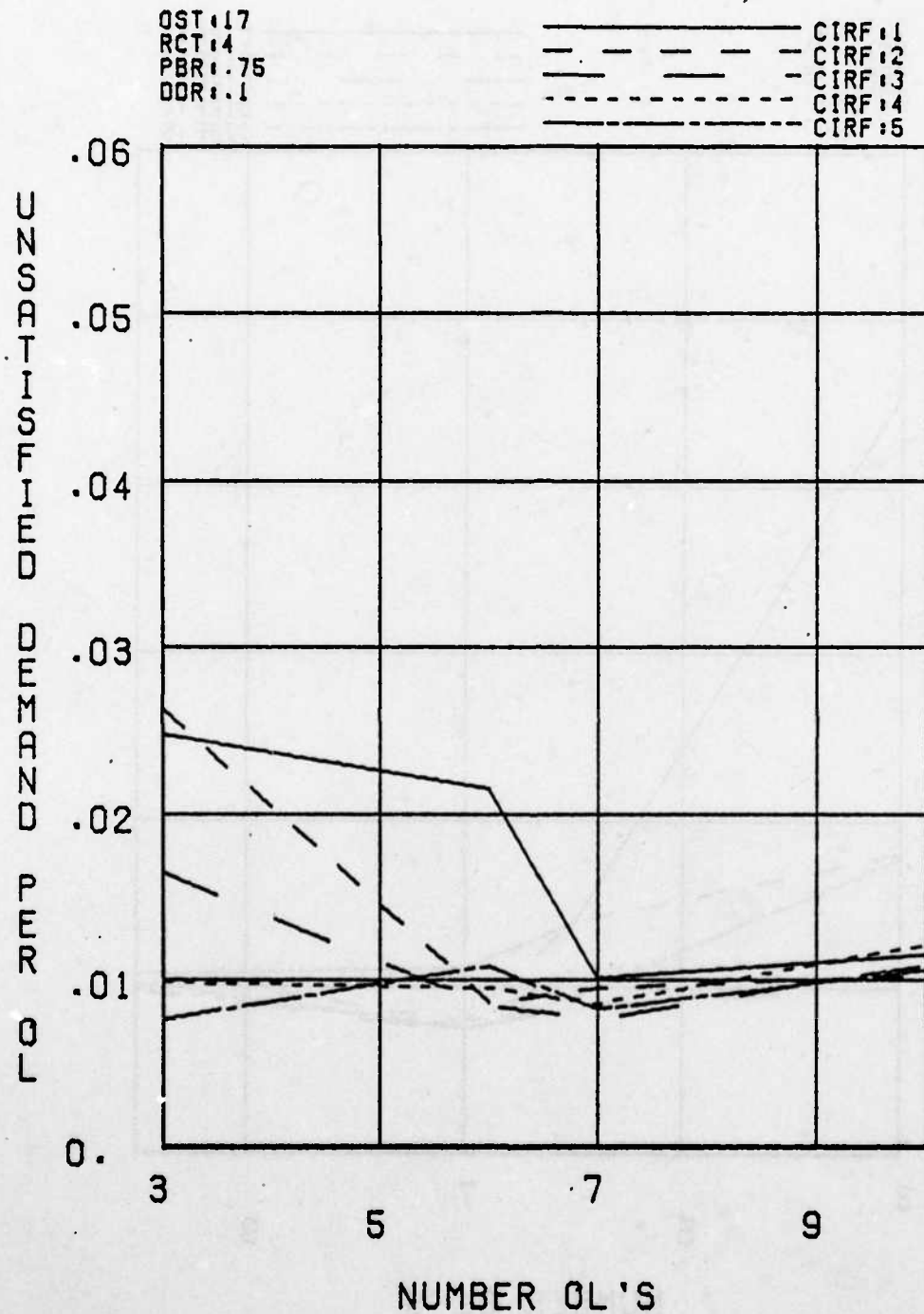FIG. 33. CIRF LOCATION EFFECT/OST:16

FIG. 34. CIRF LOCATION EFFECT/OST:17
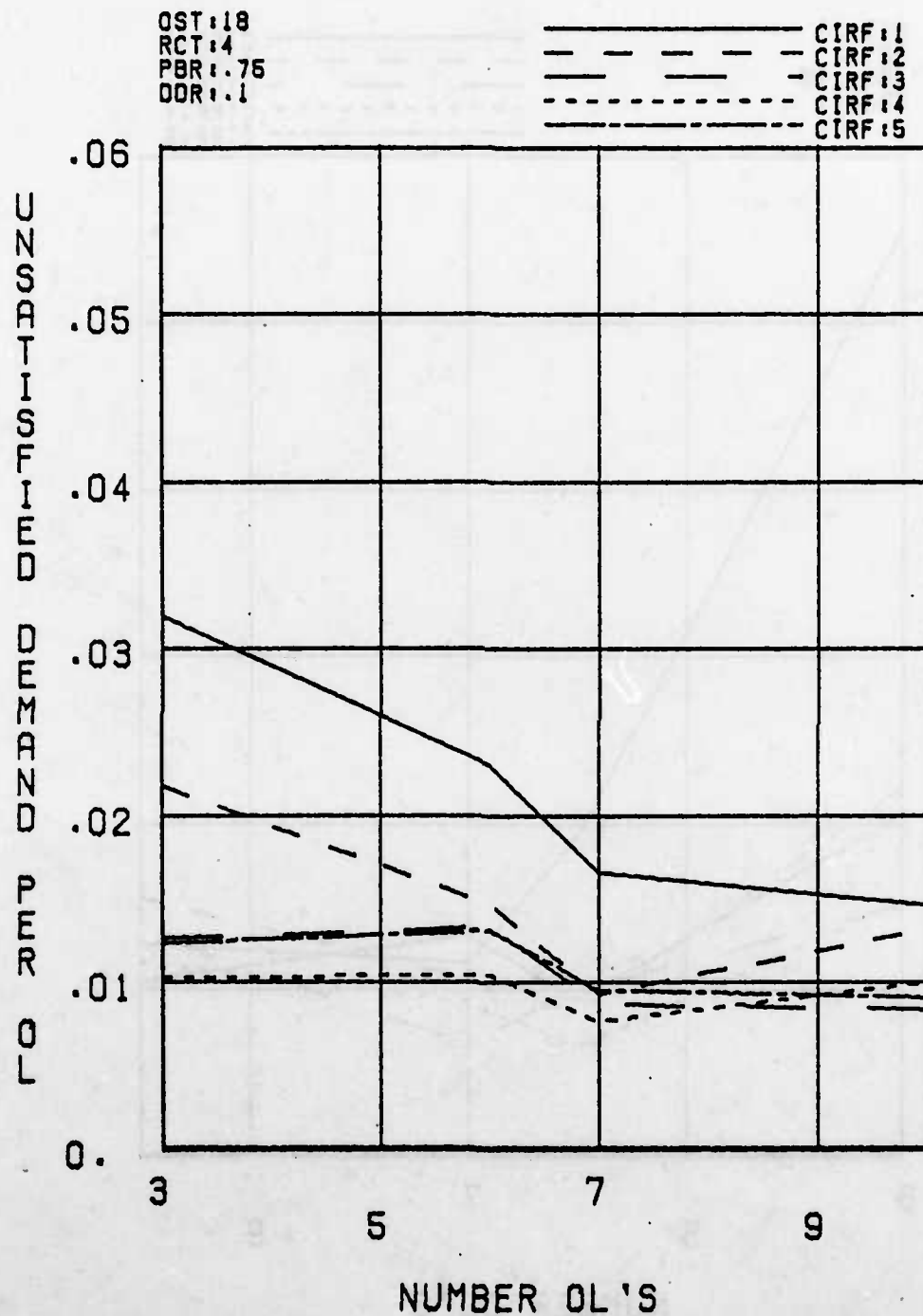
FIG. 35.   CIRF LOCATION EFFECT/OST:18

69
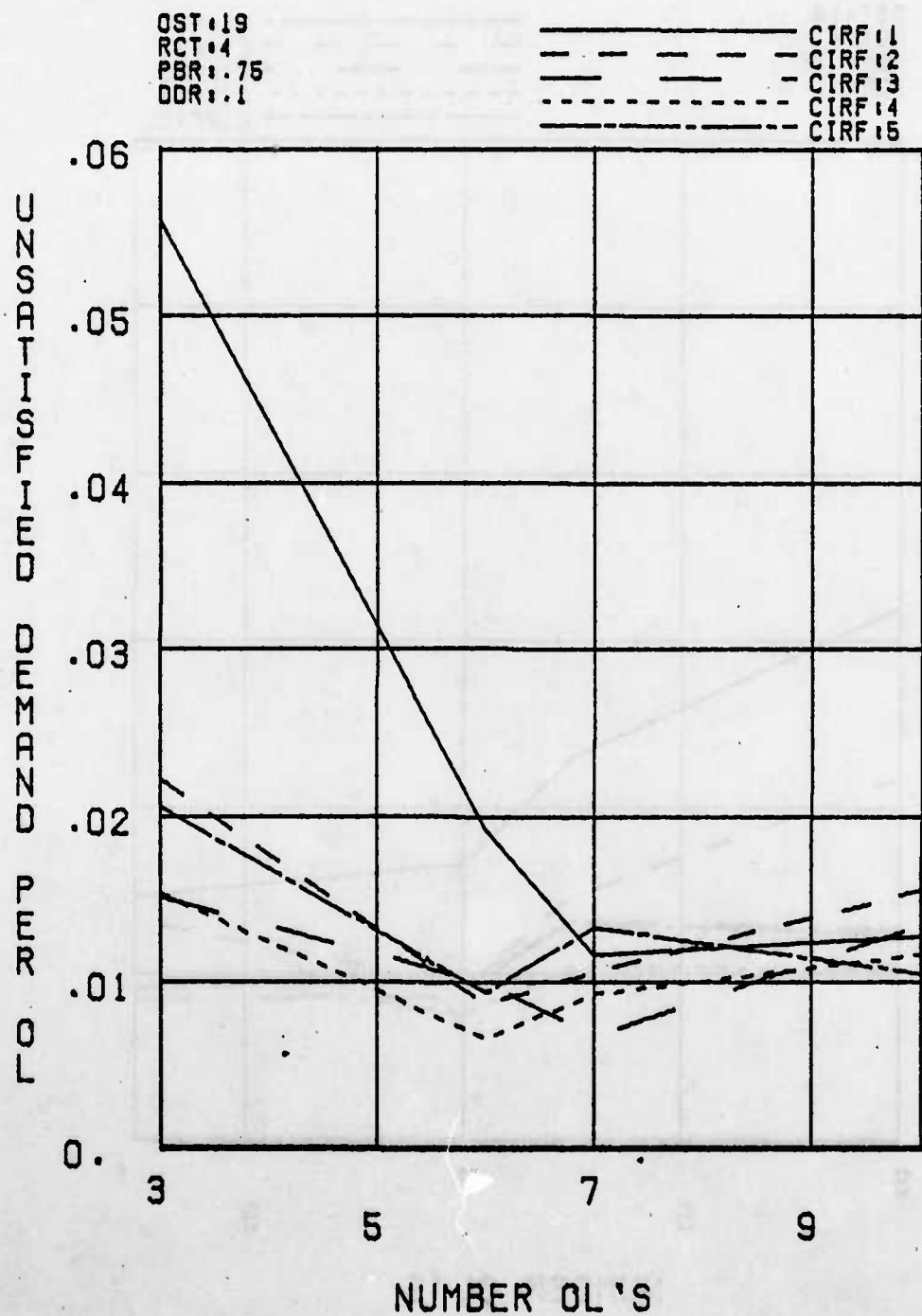
FIG. 36.   CIRF LOCATION EFFECT/OST:19

70
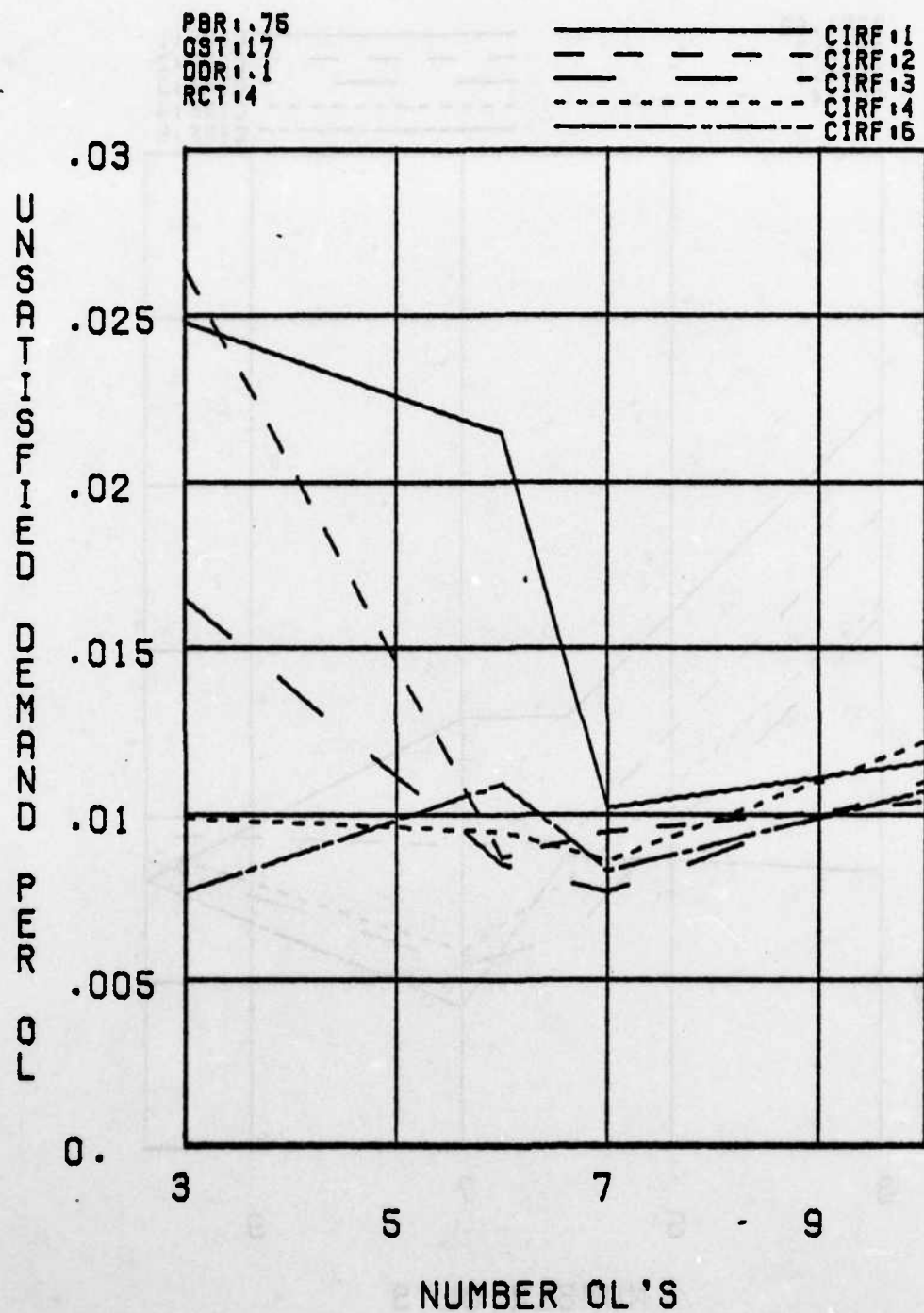
FIG. 37. CIRF LOCATION EFFECT/PBR:.75

71

FIG. 38. CIRF LOCATION EFFECT/PBR:.80

72
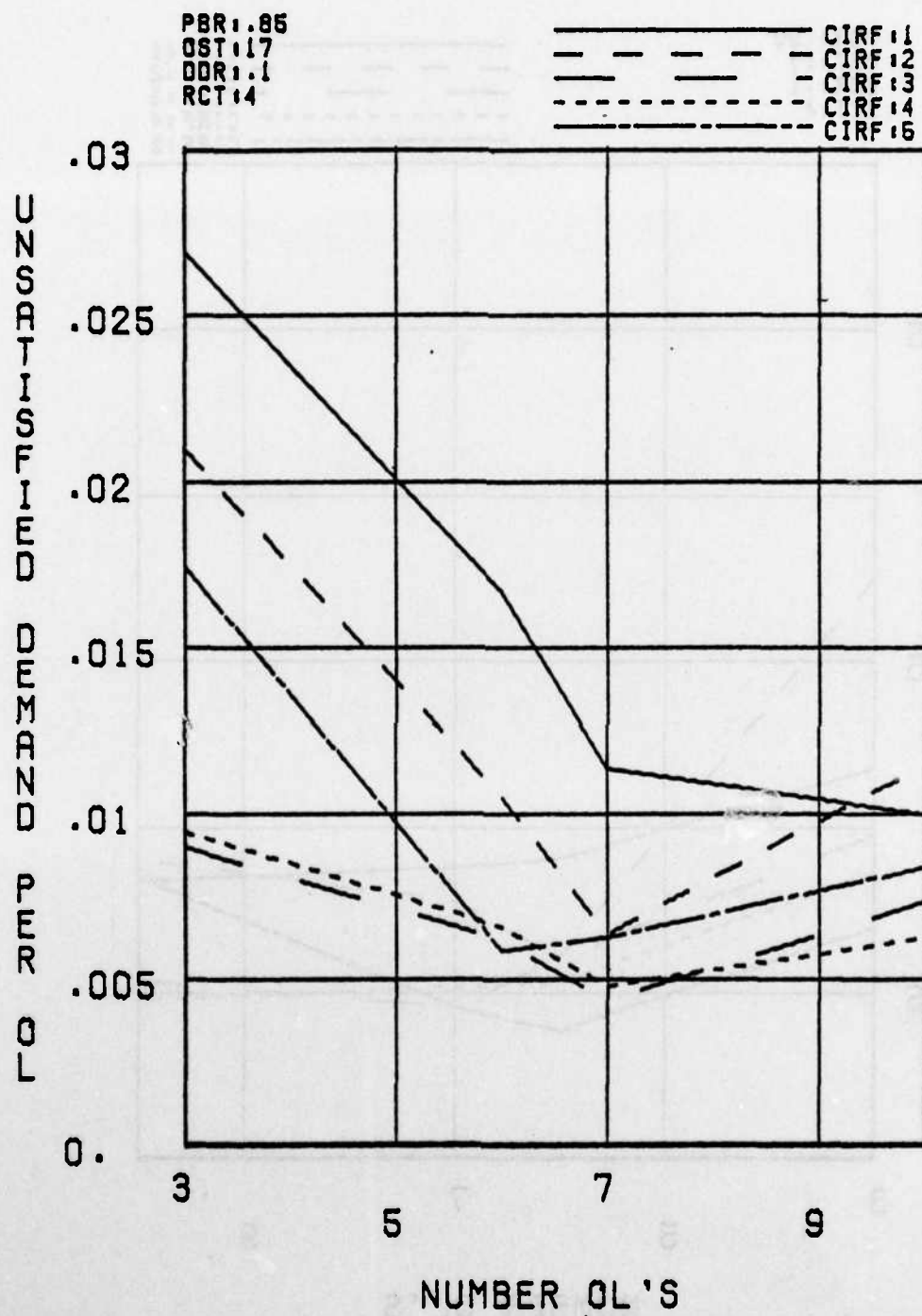
FIG. 39. CIRF LOCATION EFFECT/PBR:.85
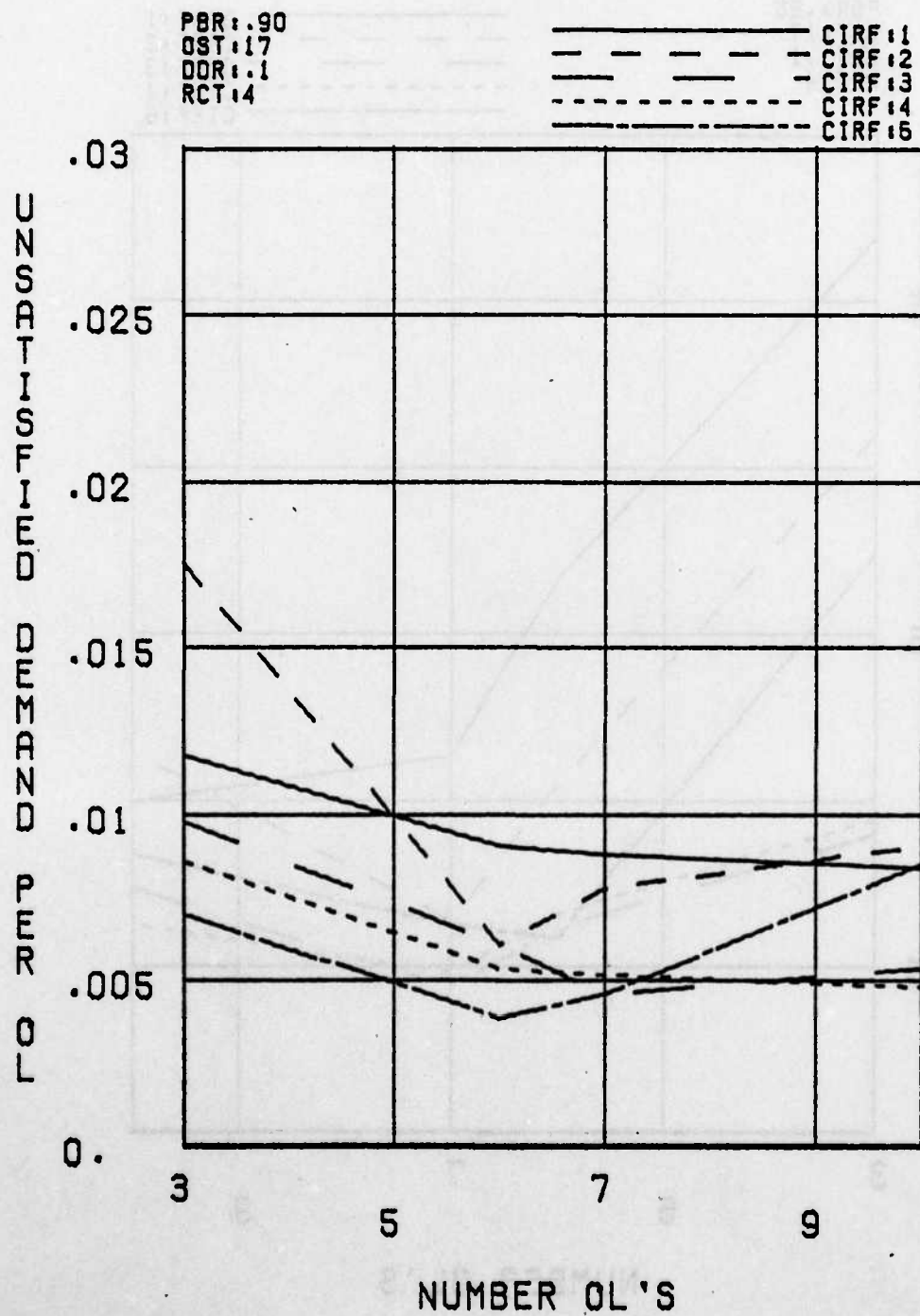
FIG. 40. CIRF LOCATION EFFECT/PBR:.90

74
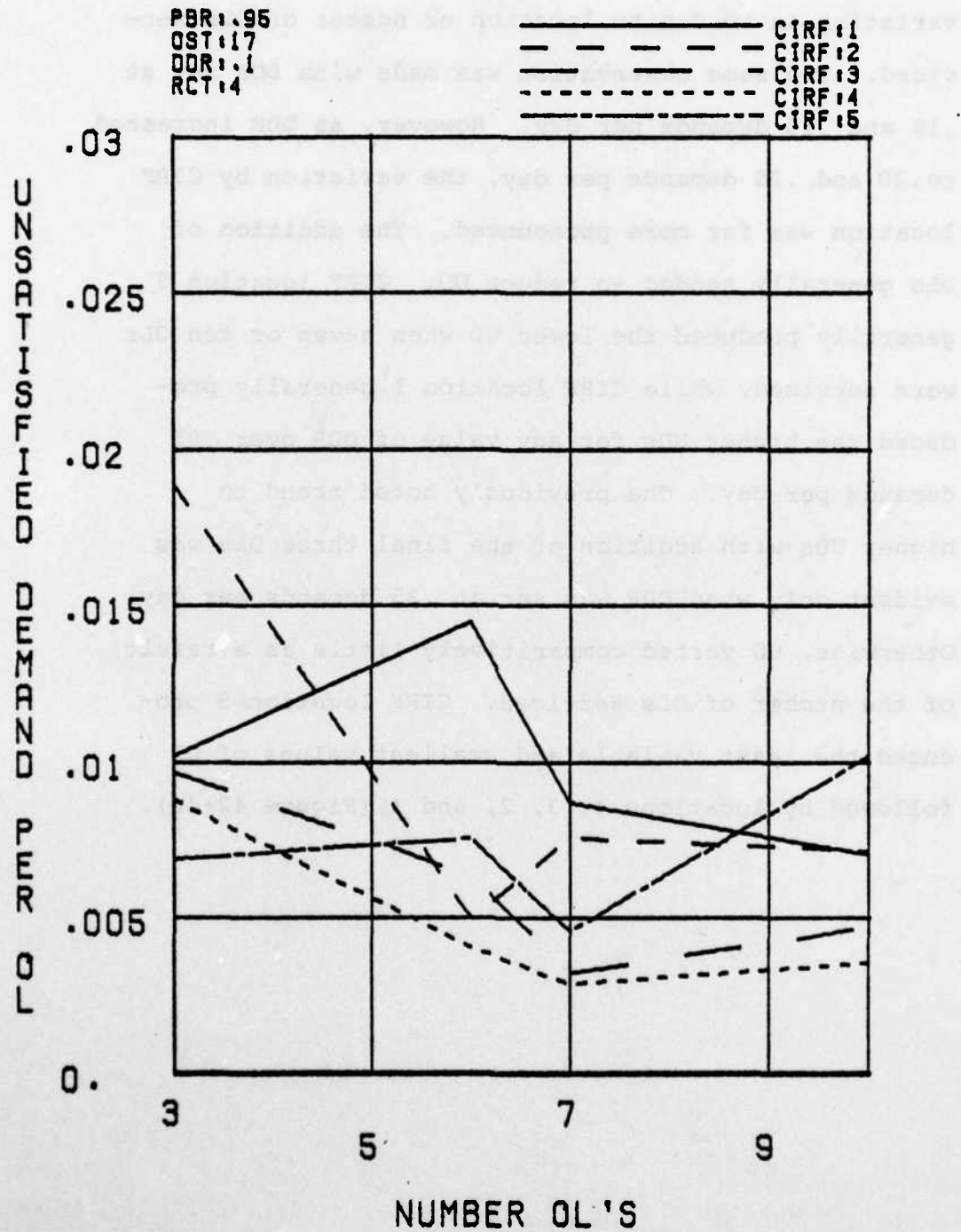
FIG. 41.   CIRF LOCATION EFFECT/PBR:.95

variation in UD due to location or number of OLs ser-
viced. The same observation was made with DDR set at
.10 and .15 demands per day. However, as DDR increased
to .20 and .25 demands per day, the variation by CIRF
location was far more pronounced. The addition of
OLs generally tended to reduce UD. CIRF location 3
generally produced the lower UD when seven or ten OLs
were serviced, while CIRF location 1 generally pro-
duced the higher UDs for any value of DDR over .05
demands per day. The previously noted trend to
higher UDs with addition of the final three OLs was
evident only when DDR was set at .25 demands per day.
Otherwise, UD varied comparitively little as a result
of the number of OLs serviced. CIRF location 5 pro-
duced the least variable and smallest values of UD
followed by locations 4, 3, 2, and 1 (Figure 42-46).

76
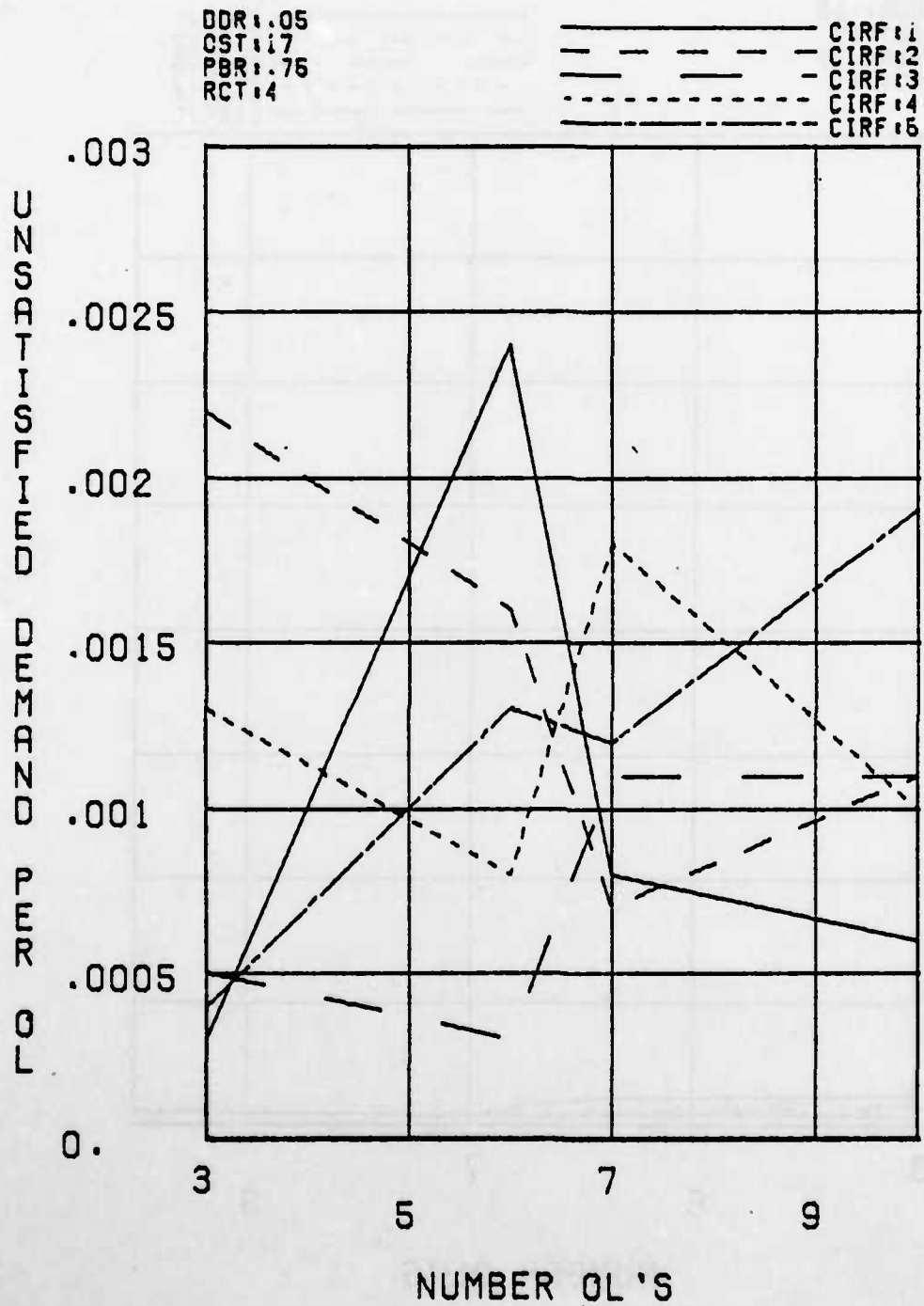
FIG. 42. CIRF LOCATION EFFECT/DDR:.05

77

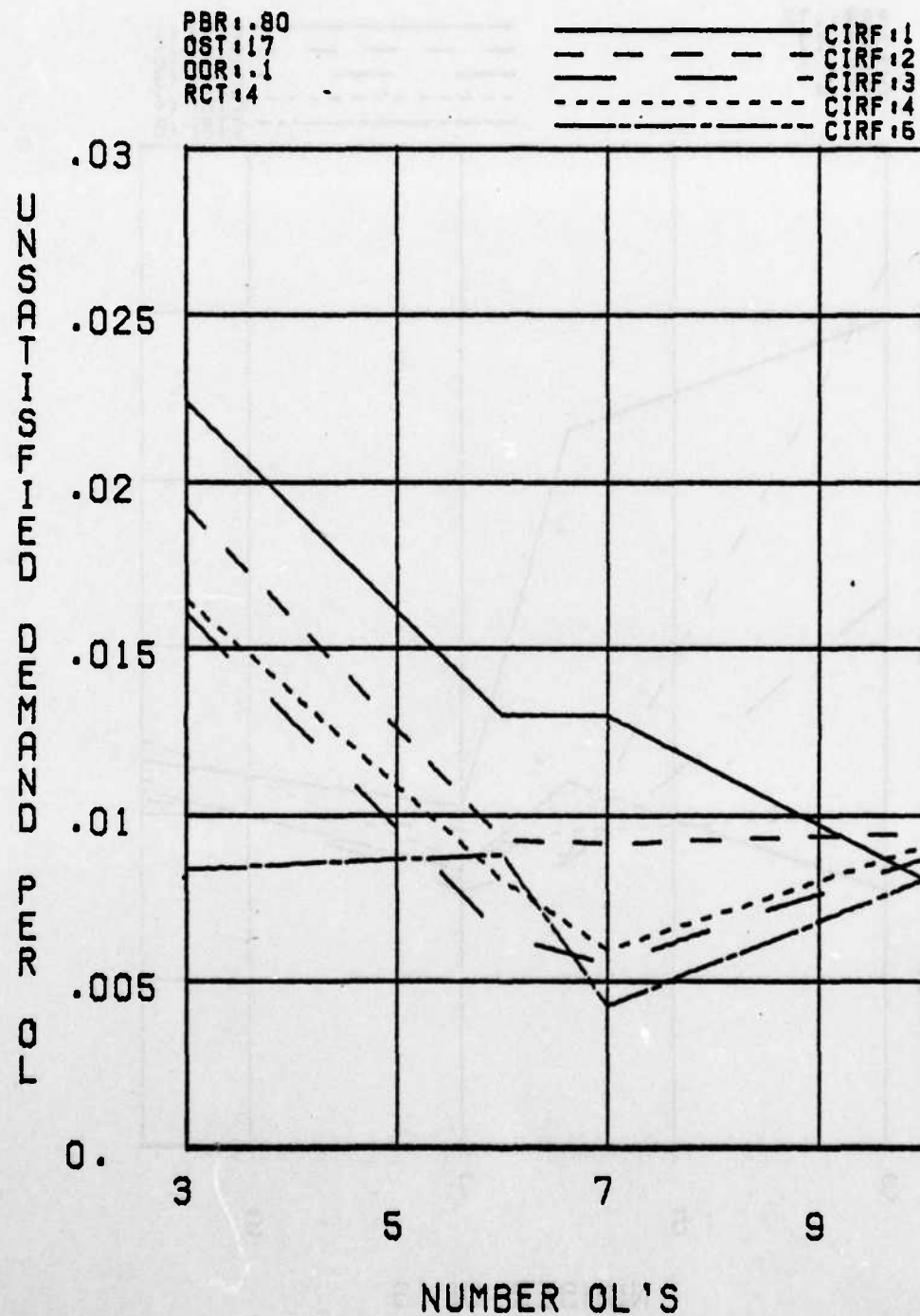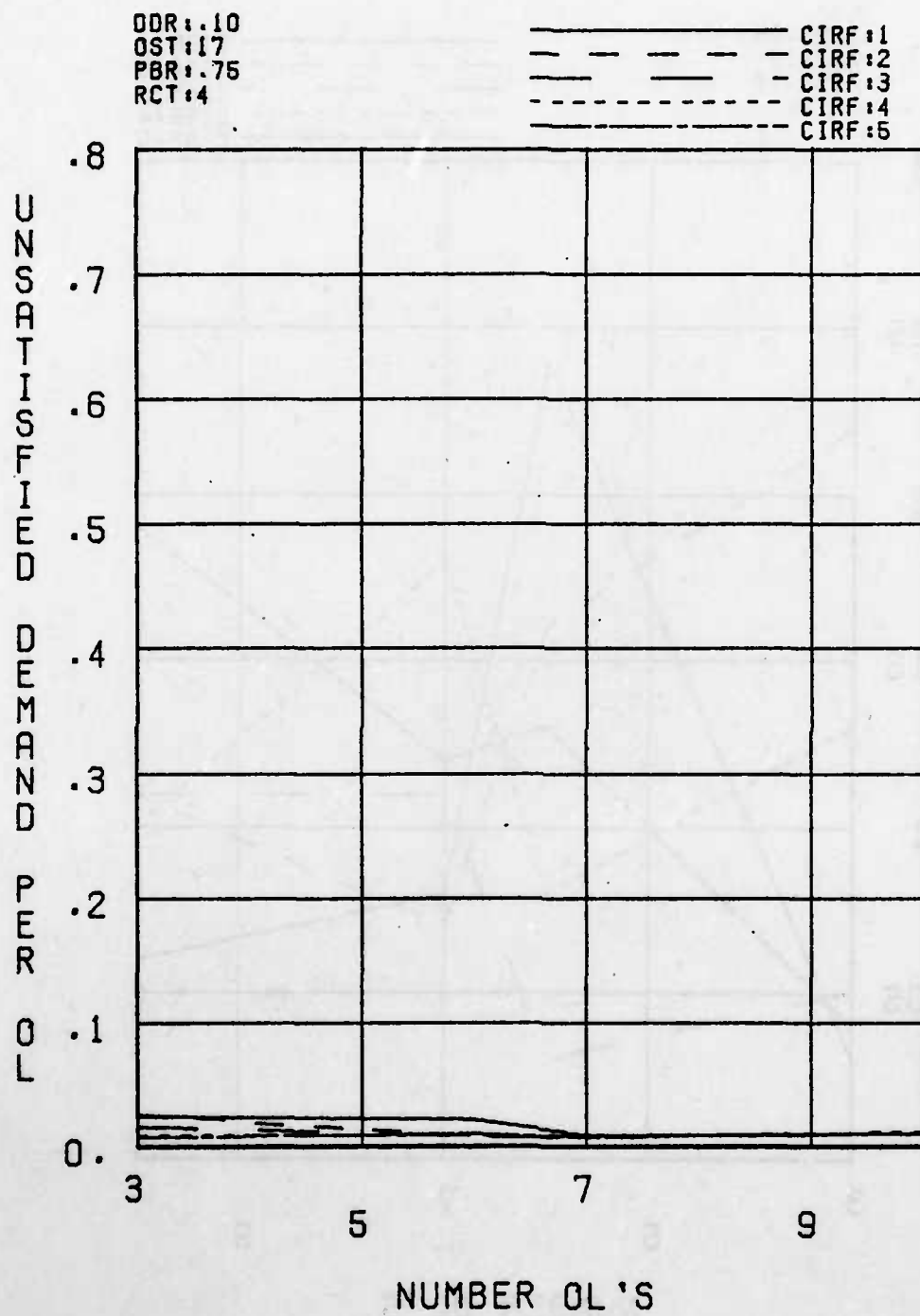FIG. 43. CIRF LOCATION EFFECT/DDR:.10
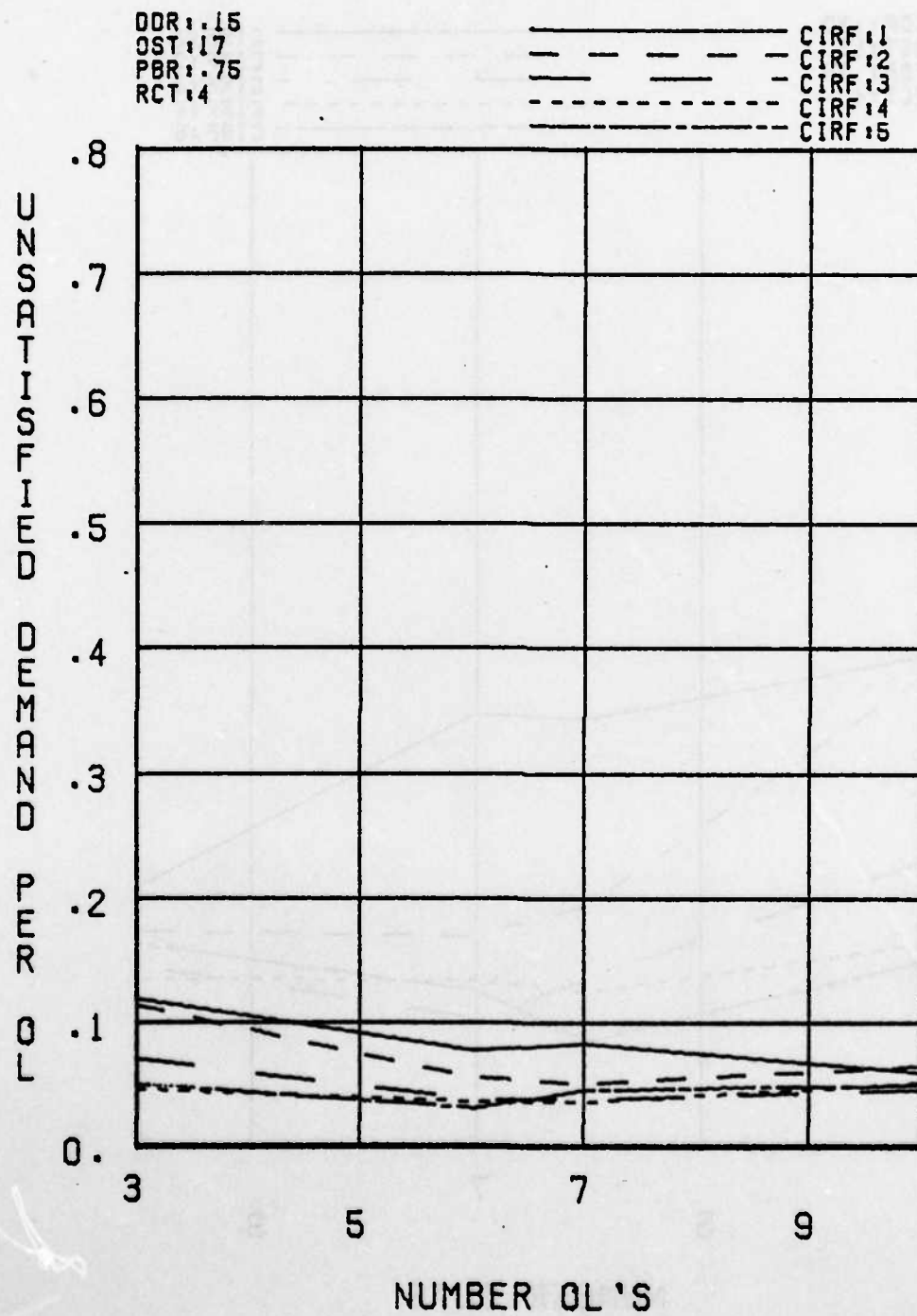
FIG. 44. CIRF LOCATION EFFECT/DDR:.15
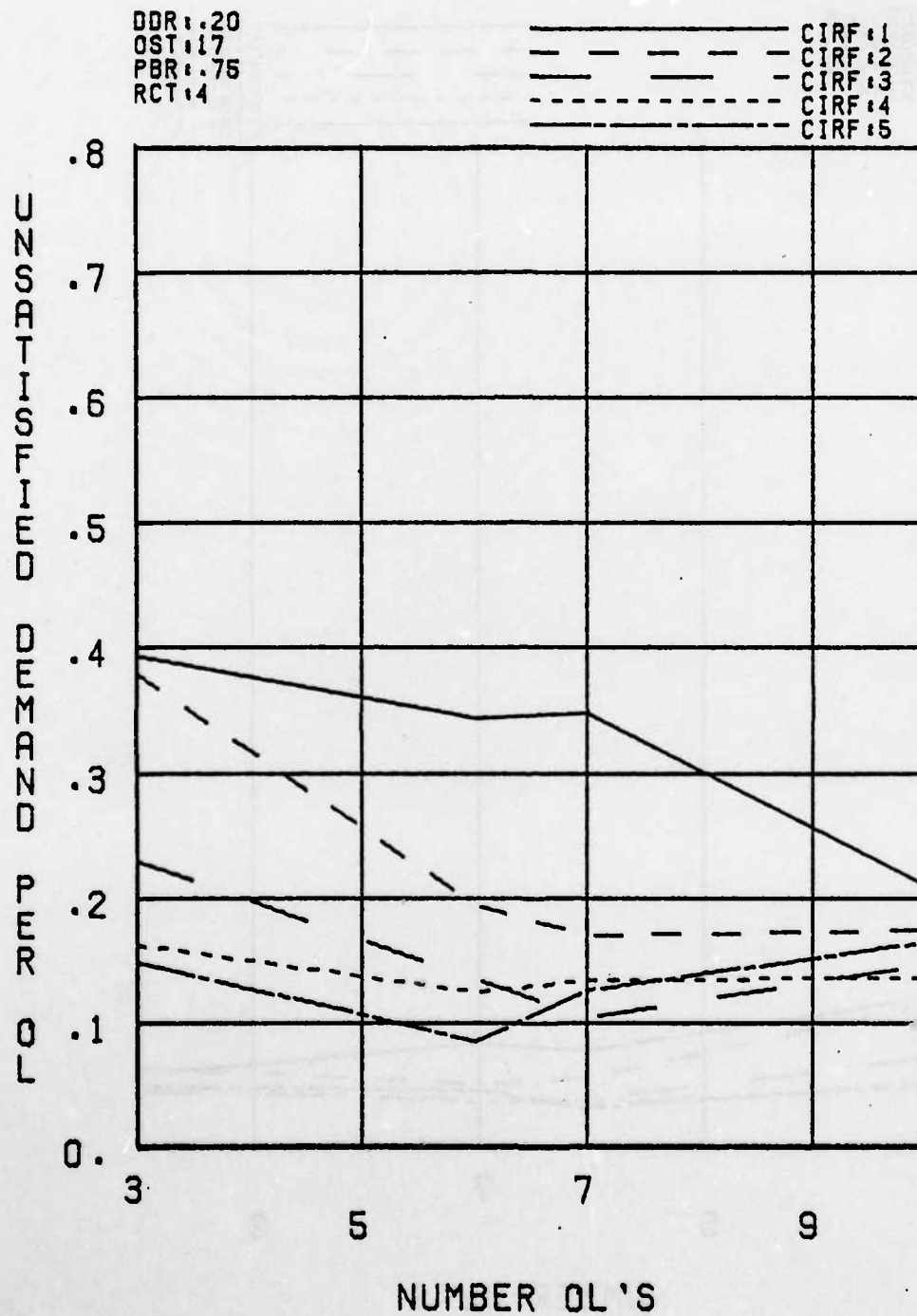
79

FIG. 45. CIRF LOCATION EFFECT/DCR: 20

4722

1.0

2.8 2.5

3.2 2.2

3.6

4.0 2.0

1.1

1.8

1.25 1.4 1.6
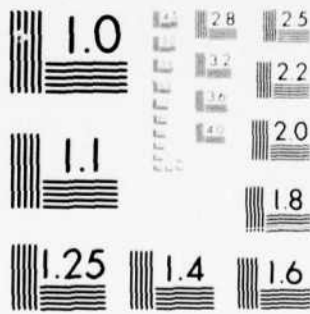
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNSATISFIED DEMAND PER OL

.8

.7

.6

.5

.4

.3

.2

.1

0.

3   5   7   9

NUMBER OL'S
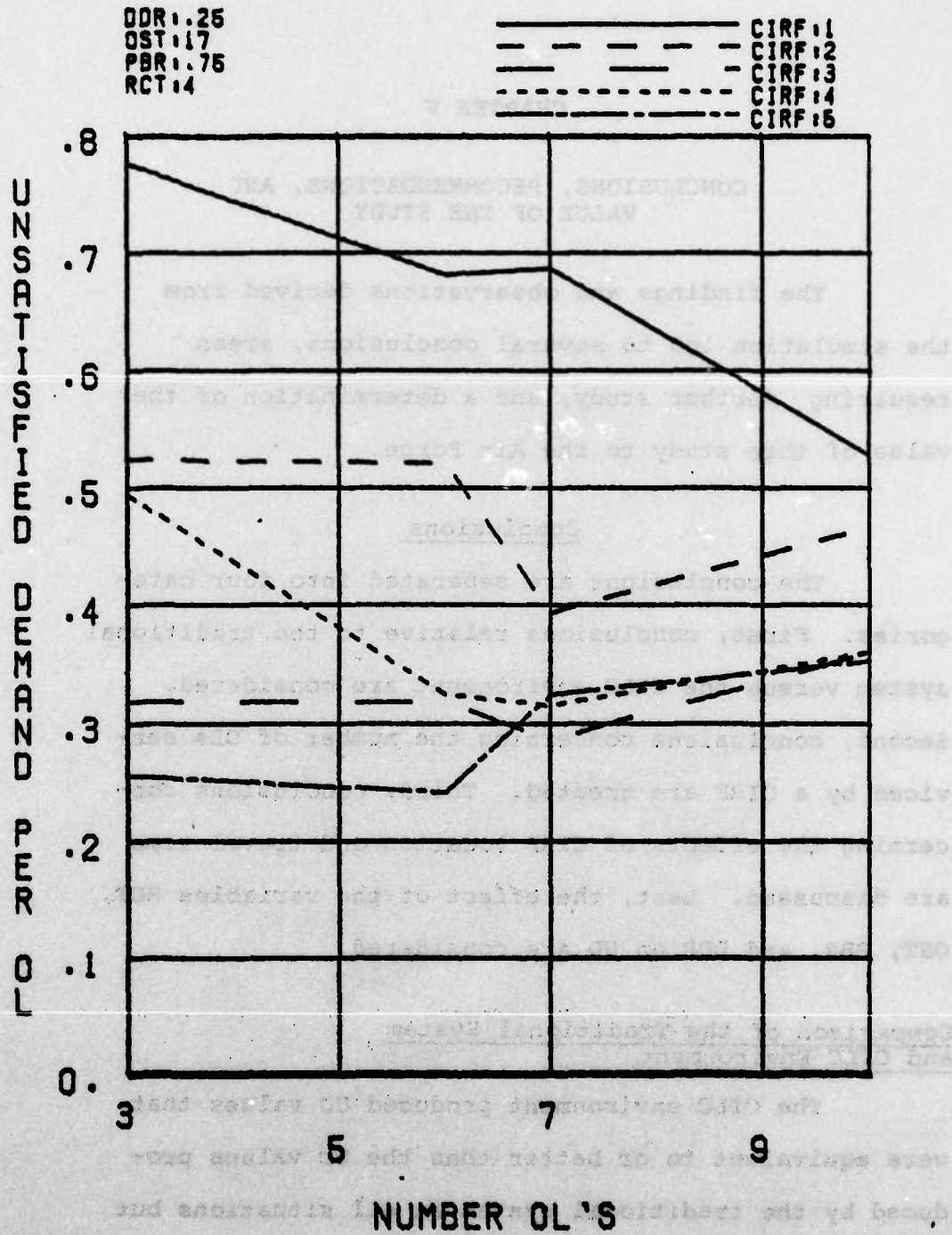
FIG. 46.   CIRF LOCATION EFFECT/DDR:.25

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS, AND
VALUE OF THE STUDY

The findings and observations derived from
the simulation led to several conclusions, areas
requiring further study, and a determination of the
value of this study to the Air Force.

Conclusions

The conclusions are separated into four cate-
gories. First, conclusions relative to the traditional
system versus the CILC environment are considered.
Second, conclusions concerning the number of OLs ser-
viced by a CIRF are treated. Third, conclusions con-
cerning the effects of CIRF location and travel time
are discussed. Last, the effect of the variables RCT,
OST, PBR, and DDR on UD are considered.

Comparison of the Traditional System
and CILC Environment

The CILC environment produced UD values that
were equivalent to or better than the UD values pro-
duced by the traditional system in all situations but
CIRF location 1. As the CILC RCTs were increased, this

performance advantage diminished until, at a CILC RCT
of seven days, rough equivalence was achieved with the
traditional system having an RCT of four days. The
conclusion was reached that the CILC environment must
be able to generate RCTs that are approximately equi-
valent (within two days) to those of the traditional
system to achieve superior supportability. However,
these results were achieved with the CIRF environment
utilizing the designated transportation situation, i.e.,
the given transportation time relationships to include
every other day transportation between England and
the continent. Perhaps more frequent transportation
between England and the continent would produce
improved UD for at least CIRF location 1 scenarios.
This analysis amends previous studies by demonstra-
ting that CILC can be a superior maintenance concept
and, therefore, merits additional extensive examination.

Number of OLs serviced by a CIRF

As a CIRF serviced more OLs, generally a reduced
UD was observed independent of the value of the other
variables in the scenarios. The effect of CIRF loca-
tion was diminished as more OLs were serviced. Ser-
vicing more OLs also reduced the effect of RCT, OST,
PBR, and DDR on both the magnitude and variation of

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UD. The phenomenon could be termed "consolidation effect": As more OLs were added to the CILC environment, there were more sources for lateral borrowing in the event of a stockout situation at a particular OL. If this effect was occurring, the addition of more OLs to the environment would account for the overall lower UDs and the attinuated effect of the variables. An application of this effect concerned CIRF location 1. Although distant in travel time (every other day service) to its OLs in the 3, 6, and 7 OL scenarios, there was a general decrease in UD as the number of OLs increased from three to six. UD was further reduced with addition of the seventh OL to the environment. This effect is potentially important in the CILC environment because of its ability to reduce the undesireable effects of some variables in the environment (high RCT or DDR, for example).

The conclusion was that the addition of OLs with relatively long transportation times to existing OLs tended to increase UD, however, the effect was not pronounced. This was illustrated by the addition of the last three OLs (in England) to the existing environment of seven OLs. Although the concept was not explicitly tested, the consolidation effect

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might have mitigated a substantial portion of the effect of the final addition: had there been only three OLs in the environment instead of seven, the effect might have been more pronounced.

CIRF Location and Travel Time Effects

The generally lower UDs produced by CIRF locations 3 and 4 implied that the location of the CIRF such that total travel time between CIRF and all OLs was minimized (at the system's center of mass) would reduce both the value and variation in UD. The CIRF located closest to the environment's center of mass generally produced the lowest UDs. However, this generalization appeared to have more impact when three OLs were serviced and less impact as six, seven and ten OLs were serviced. Increased RCTs and DDRs dramatized the effect of a centrally located CIRF.

The physical location of OLs and CIRF was not the key issue: travel time was the factor that had to be considered. Dramatic effects on UD could be realized by altering travel times in an environment, especially with relatively few OLs. This was illustrated by the addition of the last three OLs to the environment. A further illustration was a comparison of UDs by CIRF location with only three OLs in the environment. As a

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rule, the closer the CIRF was located to the environment's center of mass, the lower the UD. However, the difference between a three OL environment with a distant CIRF and one with a relatively close CIRF (relative to travel time) was as much as 700 percent. In the design of the CIRF environment, this dramatic effect must be considered. A heavy penalty in supportability is paid by locating the CIRF away from the center of mass in an environment with few OLs.

UD as Affected by RCT, OST, PBR, and DDR

UD varied directly with RCT. As could be expected, an increase of RCT with a given CIRF location generally produced a greater and more variable UD. It was noted that the effect could be mitigated by a CIRF location close to the center of mass and/or by increasing the number of OLs.

OST had relatively little effect in any scenario examined; reduced OSTs decreased UD very little and increased OSTs increased UD very little. In this study, the baseline value of PBR was set at 75 percent. Therefore, this conclusion should be valid for any PBR above the 75 percent figure since OST was only a factor if an LRU could not be repaired at the CIRF.

The effects of PBR were inconclusive. Although a decrease in PBR generally resulted in an increase in UD, the available data indicated neither definite trends nor supportable conclusions. Since some of the decreases in PBR indicated rather large proportional changes in UD, the implication exists that PBR could be a major factor in UD, especially if the DDR was high (the higher DDRs affected UD much more than the lower DDRs). Therefore, a high DDR and a low PBR combined with a high OST could drastically affect UD.

DDR was the most significant variable in terms of impact on UD: it produced the largest regular increase in the environment of any of the variables. In an environment where the CIRF was located closest to the center of mass, and increased numbers of OLs were serviced, the effect of DDR was reduced, but it was the most significant variable of the four.

In conclusion, by accomplishing the research objectives, the research question was partially answered. Through wave studies five of six variables were selected that were believed to have a significant impact on supportability. The final variable, number of OLs, was relected because of the generalized nature of the study. The simulation program was obtained from an existing program and adapted to the needs of the study by increasing the number of OLs that could

be handled and by modifying the lateral borrowing logic.
Finally, an evaluation of the traditional maintenance
system versus the CILC environment was made and the
relationships between the variable selected and air-
craft supportability were determined within the con-
fines of the experimental design. Some insight was
obtained as to the nature of the effects of RCT, OST,
PBR, and DDR on the CILC environment. Generally,
DDR produced the most significant impact on support-
ability followed by RCT, PBR, and OST, in that order.

Recommendations for Further Study

This study effort was the start of a larger
investigation to learn more about the generalized CILC
environment. During the course of this study, the need
for more experimentation became obvious. The need of
further experimentation was a direct result of the
knowledge gained in this work. The suggestions are in
three areas: design of the simulation, comparison of
the traditional system to CILC, and sensitivity analyses
of the CILC environment.

In working with the Malis Simulation, several
questions arose concerning certain logic; particularly,
lateral borrowing logic and repair policies at the CIRF
and depot. The employed lateral borrowing logic stated
that priorities were established when an OL was without

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an LRU; it sought the OL with the largest stock and
broke ties by choosing the OL that was closest timewise.
In reality, this may be an overly simplified outlook on
the lateral borrowing process that would occur. Since
the CIRF would probably exercise control over the assets
consideration might be given to the time the next repaired
LRU is due out of the CIRF. Also, with the scenarios
in the generalized CILC environment differing from those
of the PACAF environment, further consideration should
be given to the policy of zero stock at the CIRF and
whether it is the optimal policy in all environments.
Still another area that could be investigated concerns
repair policies at the CIRF and depot.

It is known that LRUs are not always repaired
immediately upon arrival at a repair facility; some
batch processing or awaiting parts conditions could
occur in the course of time. An effort should be made
to determine the actual state of the repair facilities
and to incorporate the findings in the simulation logic.
The second area of suggested additional study concerns
the comparison of the traditional system and the CILC
environment.

In this study, only an initial effort was made
to investigate the differences between these two main-
tenance environments. An investigation similar to that
which has been performed on the variables in the CILC

environment might be performed with the traditional environment for comparison purposes. In this way, the relative strengths and weaknesses of the two environments with different scenarios may be discovered. The last area of suggested study concerns additional investigation of the CILC environment itself.

In the design of this study, many important variables were excluded from investigation; specifically, stock and WRSK levels, decision times at strategic points in the maintenance cycle[2] and travel time. For a more complete understanding of the CILC environment, these variables should be investigated. The variable travel time is recommended to be studied separately. In this effort, the researchers were forced to specify fixed OLs and CIRFs because of the complexity of the travel relationships. This complexity lends itself to a separate study. The final area of recommended study concerns the stochastic nature of the simulation.

In a limited study effort relatively few simulation runs were performed (less than 500). As stated in Chapter II, the short simulation time was

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[2]These times include: time between demand and issue, time to check the WRSK, time to check for lateral support, time required to make a decision at the CIRF whether to repair or order from the depot, and decision time required at the CIRF as to where to allocate a repaired LRU.

considered important to realistic simulation. Therefore, without sacrificing the short simulation time, a better idea of the nature of the environment could be obtained by executing more runs for each CILC condition and the average of these used in plots. In this effort each point on a graph represents the output from one run.

Value of this Study to the Air Force

At a time when increased performance is demanded for each defense dollar invested, the CILC concept appears to be a candidate for further consideration for adoption. In a simulation approximating the European theater, it was demonstrated that, in a majority of cases, CILC surpassed the supportability of the traditional maintenance system. The CICL concept can, theoretically, be employed to increase supportability, reduce costs of maintenance, or a combination of the two.

In light of the positive results of the PACAF field test and the favorable correlation of the Malis Simulation with those results, this study takes on added importance. Because of the favorable correlation of simulation and field test results, the generalized simulation should give a reliable picture of the generalized CILC environment. With this tool, it is now possible to attempt to further the basic understanding of the

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generalized CILC environment, a concept experimentally
demonstrated to be potentially superior to the tradi-
tional maintenance concept.

The results of this study will hopefully pro-
vide a sound basis for the further research of a
promising concept.

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APPENDIXES

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APPENDIX A

DEFINITION OF TERMS AND EQUATIONS

Aircraft-NORS Hours

The number of aircraft hours lost from mission duties due to the aircraft being not operationally ready due to supply (9:11).

Back Order Rates (BOR)

The percentage of demands which cause backorders, i.e., which occur simultaneously with a zero stock level (9:10).

Daily Demand Rate (DDR)

Rate at which a given part fails at each base. The DDR is expressed in units of demand per day and varies according to type of LRU. The CILC simulation deals with only one type LRU per run (9:9).

Line Replaceable Unit (LRU)

End item. That piece of aircraft equipment dealt with at field maintenance level (15:3).

NORS Rates

An aircraft-NORS (Not Operationally Ready, Supply) condition exists when an aircraft is unable to perform its scheduled mission due to nonavailability of essential components. An item-NORS condition exists when a demand for a spare part cannot be immediately satisfied by any available system resource (9:10).

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Order and Shipping Time (OST)

Time required to order and receive a replacement, for a condemned or nonreparable part, from the depot (9:9).

Percentage of Base Repair (PBR)

For each part, the percentage which can be repaired at the maintenance facility (9:9).

Repair Cycle Time (RCT)

Time required to repair an LRU (6:9). In the CIRF environment this does not include transportation time to and from the CIRF.

Shop Replaceable Unit (SRU)

Subassembly of an LRU (15:3).

Unsatisfied Demand(UD)

The time-weighted average of the number of unsatisfied demands (backorders, item-NORS conditions) at a particular OL.

$$A = \left[\sum_{i=1}^{n} t_i\right] / T$$

where: A = Time-weighted average UD

n = Number of UDs observed

t_i = Duration of UD

T = Total simulation time (9:12-13).

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APPENDIX B

DESCRIPTION OF THE MODEL

The PACAF simulation model was written in FORTRAN and designed for time sharing operation on the CINCPACAF Honeywell 6060 computer, a system whose software is compatible with the AFLC Honeywell 635 computer. It utilizes the General Activities Simulation Program (GASP) developed by Pritsker and Kiviat at Arizona State University (12). GASP is a FORTRAN-based, modular, discrete event simulation package of subroutines that provides a filing framework and standard bookkeeping and statistical procedures. GASP is particularly well suited to simulation of the CILC environment because the system is driven by discrete events, such as an LRU failure, the arrival of an LRU through a pipeline, and the return to service of a repaired LRU. All of these event types can be stochastically generated according to the rules of the system. Events are maintained chronologically in a file and action is taken according to the type of event which occurs. Each event carries as "attributes" all information necessary to determine subsequent actions. Thus, the model is self-contained and requires only the initial operator input of the environmental parameters (Figure 47) (9:54).

The major GASP subroutines can be divided into several functional groups. Subroutine GASP exercises
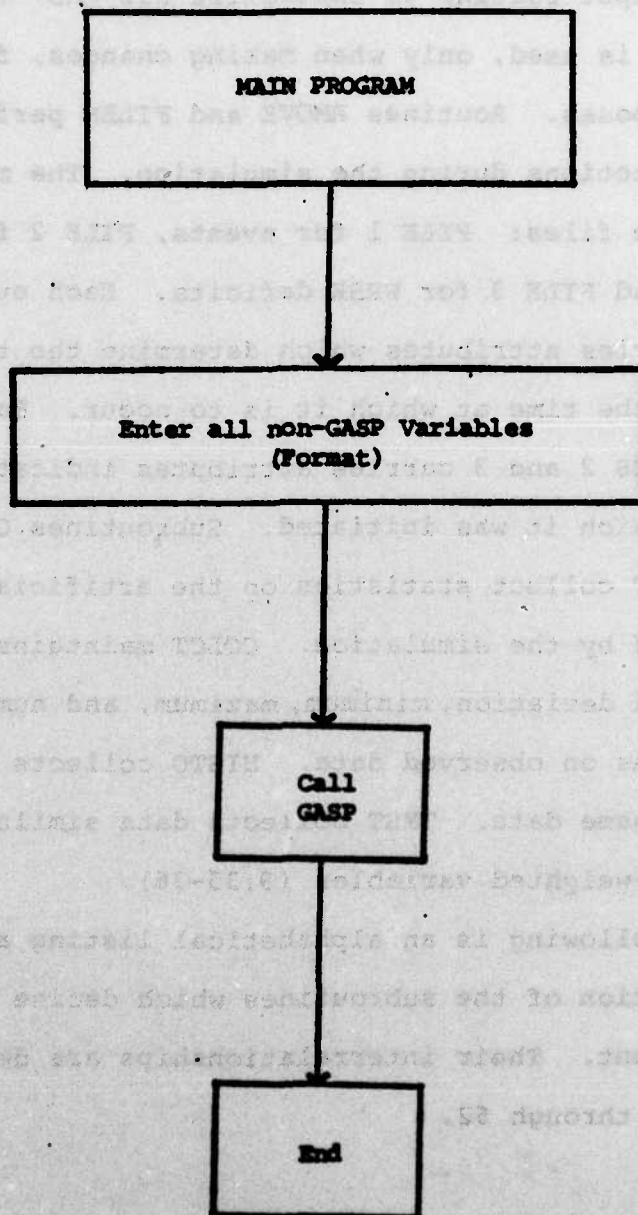
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Fig. 47. MAIN COMPUTER PROGRAM

control over the simulation process as shown in Figure 48.
DATAN is an input routine to initialize all GASP variables. MONTR is used, only when making changes, for
debugging purposes. Routines RMOVE and FILEM perform
the filing functions during the simulation. The model
requires three files: FILE 1 for events, FILE 2 for NORS
conditions, and FILE 3 for WRSK deficits. Each event
in FILE 1 carries attributes which determine the type
of event and the time at which it is to occur. Each
entity in FILES 2 and 3 carries attributes indicating
the time at which it was initiated. Subroutines COLCT,
HISTO and TMST collect statistics on the artificial
data generated by the simulation. COLCT maintains
mean, standard deviation, minimum, maximum, and number
of observations on observed data. HISTO collects histograms on the same data. TMST collects data similar to
COLCT on time-weighted variables (9:35-36).

The following is an alphabetical listing and
brief description of the subroutines which define the
CILC environment. Their interrelationships are delineated
in Figures 47 through 52.

ARRCRF

When a failed LRU is delivered to the CIRF, a
decision is made as to whether it can be repaired at that
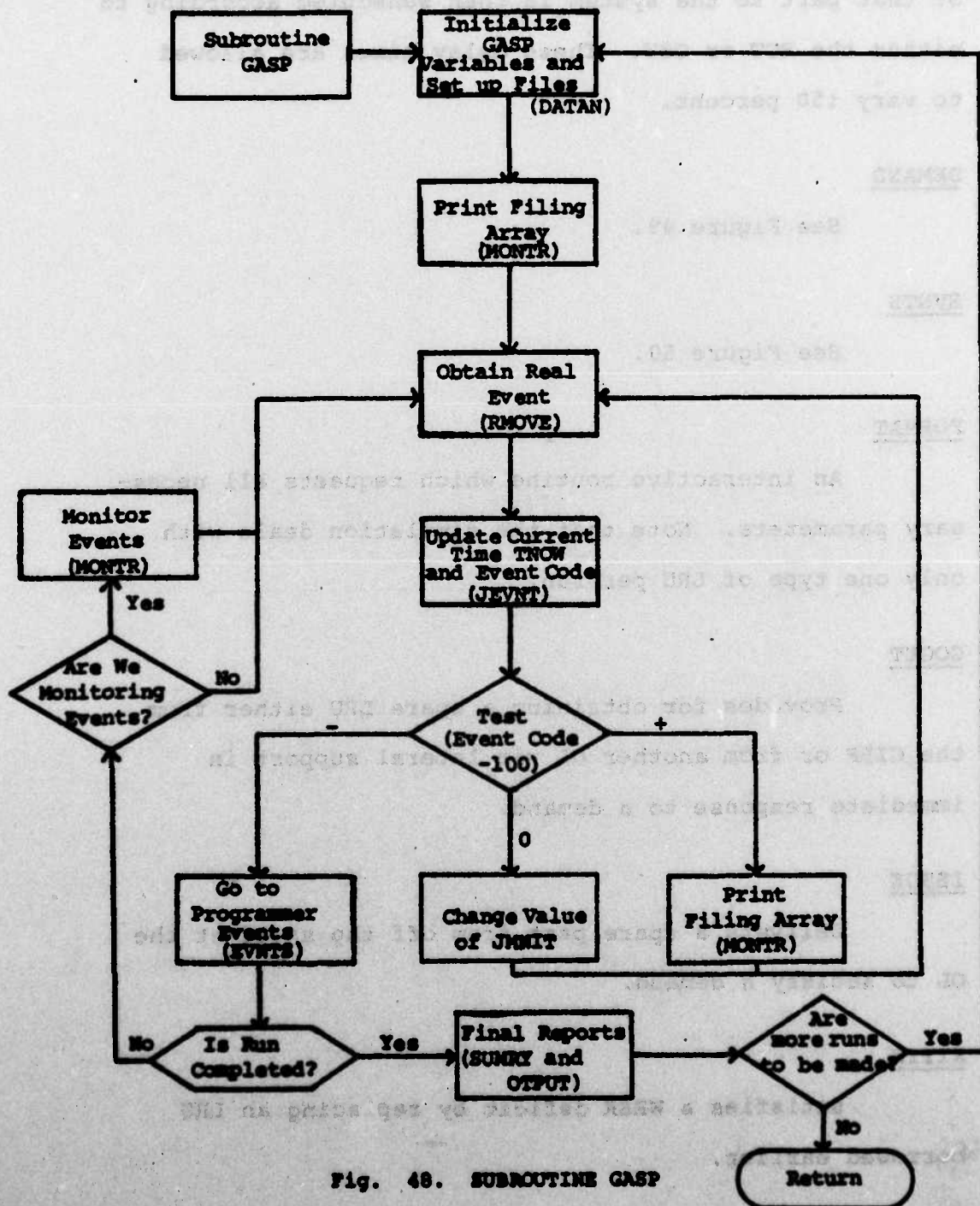facility. This is done by comparison of a generated

Fig. 48. SUBROUTINE GASP

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random number with PBR. An event signifying the return
of that part to the system is then scheduled according to
either the RCT or OST. These delay times are allowed
to vary ±50 percent.

DEMAND

See Figure 49.

EVNTS

See Figure 50.

FORMAT

An interactive routine which requests all neces-
sary parameters. Note that the simulation deals with
only one type of LRU per run.

GOGET

Provides for obtaining a spare LRU either from
the CIRF or from another OL via lateral support in
immediate response to a demand.

ISSUE

Delivers a spare part from off the shelf at the
OL to satisfy a demand.

KITIN

Satisfies a WRSK deficit by replacing an LRU
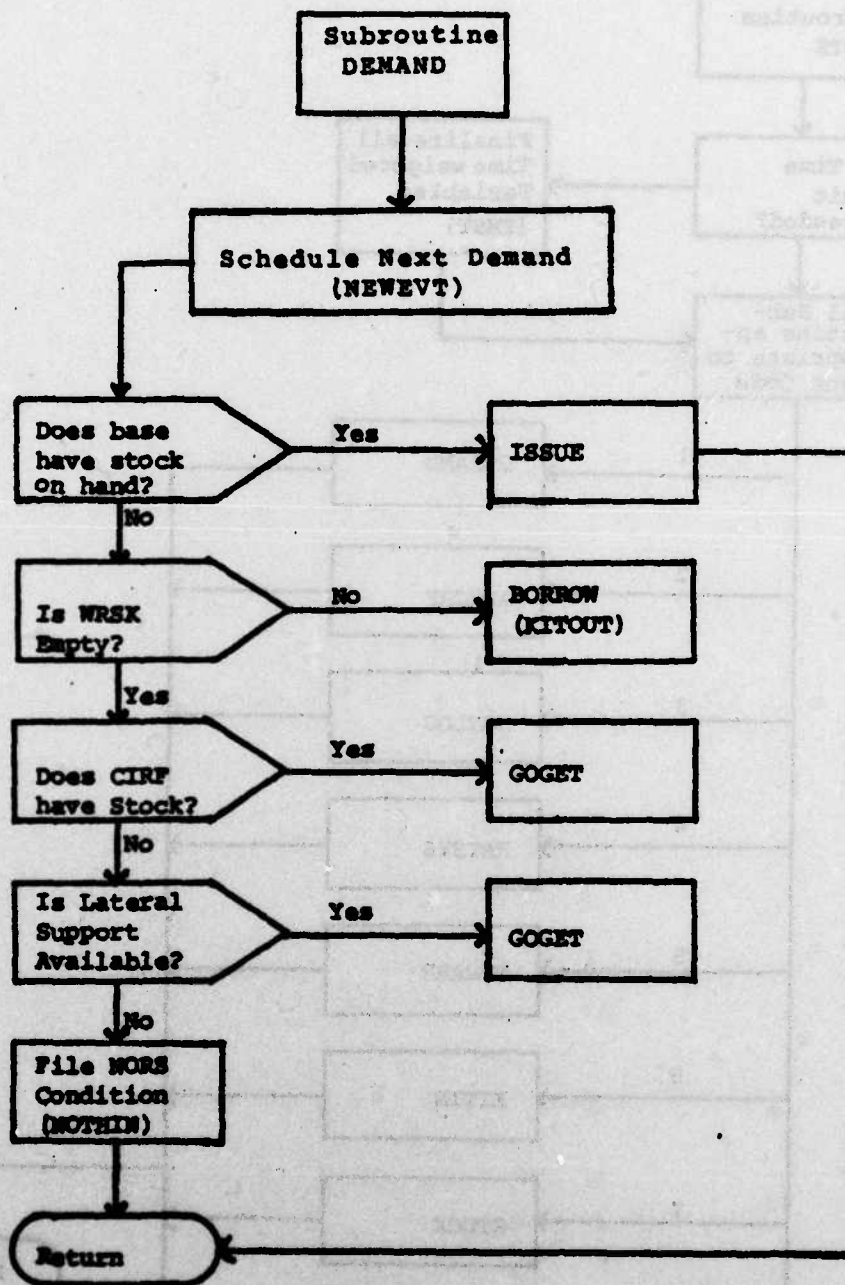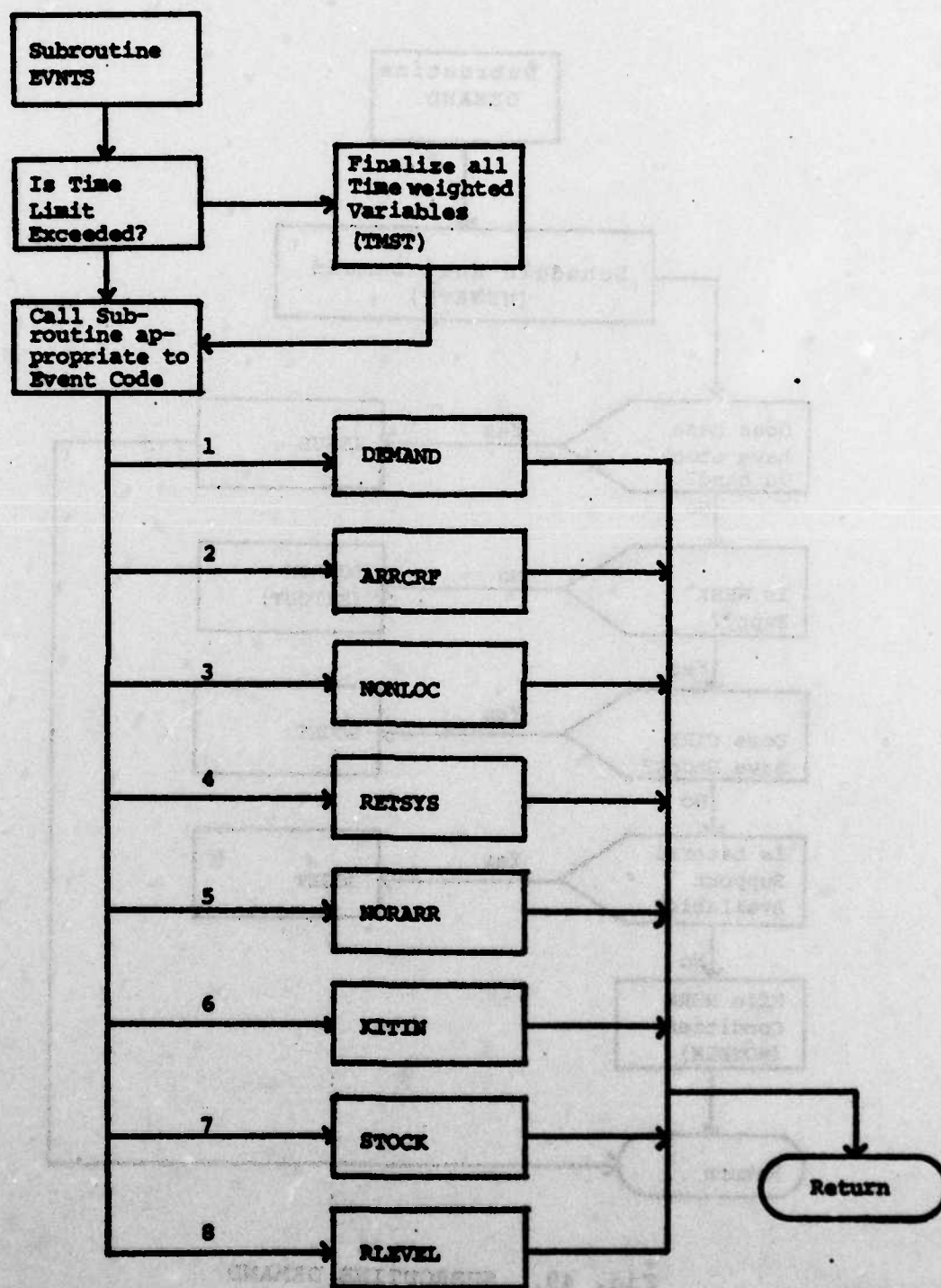borrowed earlier.

Fig. 49. SUBROUTINE DEMAND

Fig. 50.   SUBROUTINE EVNTS

KITOUT

        Creates a WRSK deficit when an LRU is borrowed
from the kit to satisfy a demand.

NEWEVT

        Schedules the next demand which is to occur.

NONLOC

        Processes the arrival of a spare LRU from
another OL; initiated by GOGET.

NORARR

        Processes the arrival of an LRU from the CIRF
to satisfy a NORS condition.

NOTHIN

        Creates and files a NORS condition when the
demand cannot be satisfied.

OTPUT

        Computes and prints out certain collected
statistics which are not handled by the automatic GASP
routines. This includes the statistic $V(I,J)$, which
denotes the percentage of time that the shelf stock at
Base I was at level J. In the program, base one is the
CIRF while bases two through four are OLs one through three.

PIPLIN

        Allows the travel time to vary ±0.5 day.

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RETSYS

Processes the allocation of an LRU once it has been repaired or received from the depot. The priority decisions are indicated in Figure 51.

RLEVEL

Provides the vehicle for modeling the periodic procedures which review and relevel stock authorizations at the various bases (Figure 52).

SHPREP

Provides for shipping a failed LRU to the CIRF.

STOCK

Increments the stock level at the base when an LRU arrives for that purpose.

VTMST

Initiates the appropriate statistical procedures every time a shelf stock level changes.

The driving force in the simulation is the rate at which LRUs fail and demands are made upon the system. As each demand occurs, the next demand must be scheduled to continue to drive the model. In this manner, the simulation continues (9:38).

The model requires an input set of variables (parameters) which describe the characteristics of a
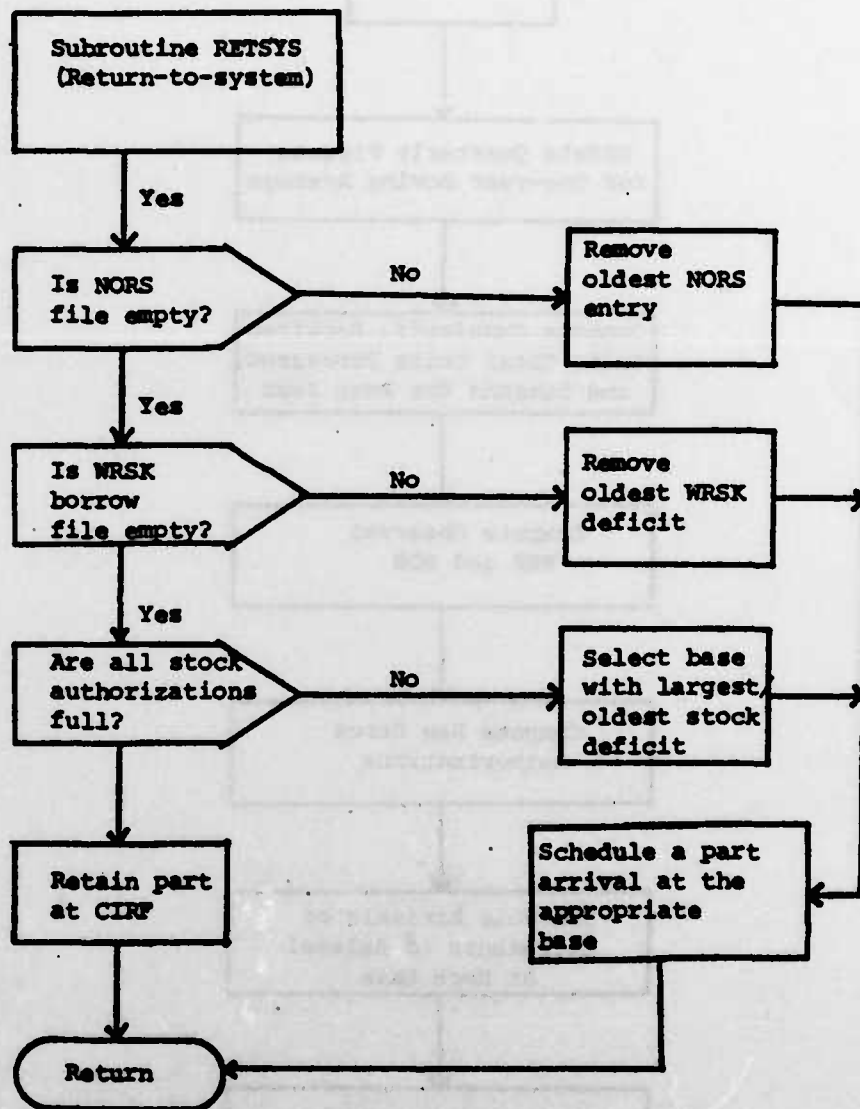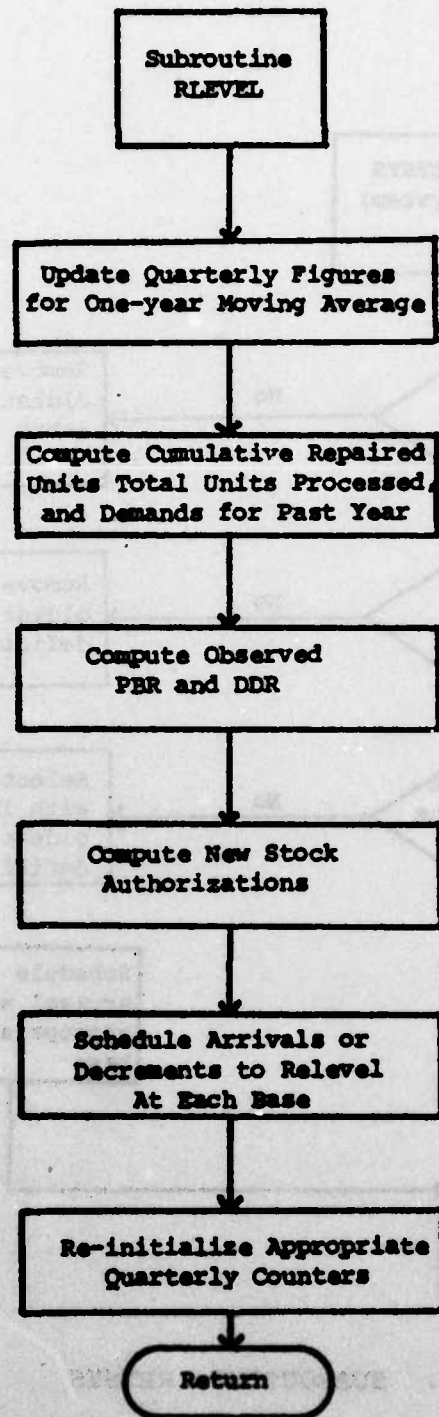
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Fig. 51. SUBROUTINE RETSYS

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Fig. 52.   SUBROUTINE RLEVEL

given LRU. RCT, OST, and PBR are input for each base
if an independent (IND) operation is desired and for
the CIRF only for a CILC environment. DDR is assumed
to be always potentially variable among the bases. Other
inputs are: (1) the travel time matrix describing
pipeline time between all bases in the system and
(2) any decision lag times (9:39).

The output of each simulation run consists of
the artificially generated data. Statistics are col-
lected on the delay times associated with satisfying
NORS and WRSK deficits and WAIT conditions. The latter
variable was created to handle backorder conditions
which did not technically satisfy the definition of
NORS as indicated in Figure 49. Other variables are con-
cerned with time-weighted averages of the number of NORS
conditions existing within the system, the number of
WRSK deficits existing, and the shelf stock level at
each base (9:39-40).

SELECTED BIBLIOGRAPHY

BIBLIOGRAPHY

1. Anderson, Richard H., and others. "Models and Methodology for Life Cycle Cost and Test and Evaluation Analysis." Unpublished Research Report No. OAS-TR-73-6, Office of the Assistant for Study Support (OAS), DCS/Development Plans, Air Force Systems Command, Kirtland AFB NM, July 1973, AD 782 182.

2. Beer, Stafford. Decision and Control. New York: John Wiley & Sons, 1966.

3. Berman, Morton B., I. K. Cohen, and Stephen M. Drezner. "The Centralized Intermediate Logistics Concept: Executive Summary." Unpublished research report No. WN-9319-PR, RAND Corporation, Santa Monica CA, 1975.

4. Crawford, Gordon B. "Stock Leveling Policies for Centralized Intermediate Repair Facilities." Unpublished Research Report, Operations Analysis Office, HQ PACAF, Hickam AFB HI, February 1977.

5. Ebeling, Major Charles E., USAF, and Major John M. Pearson, USAF. Department of Quantitative Management, Air Force Institute of Technology, School of Systems and Logistics, Wright-Patterson AFB OH. Personal interview. 7 January 1977.

6. _____. Department of Quantitative Management, Air Force Institute of Technology, School of Systems and Logistics, Wright-Patterson AFB OH. Personal interview. 7 April 1977.

7. Ford, Major Robert, USAF. Logistics Supply Systems Management Division, HQ PACAF, Hickam AFB HI. Personal interview. 18 November 1976.

8. Lu, John Y. "Analysis of Stockage Requirements for the Centralized Intermediate Logistics Concept (CILC)." Unpublished research report No. WN-9321-PR, RAND Corporation, Santa Monica CA, 1975.

9. Malis, Robert. "PACAF CILC Simulation," Unpublished master's internship paper. Wright State University, Dayton OH, 1976.

10. Muckstadt, John A. "The Consolidated Support Model (CSM): A Three Echelon, Multi-Item Model for Recoverable Items." Unpublished research report No. R-1523-PR, RAND Corporation, Santa Monica CA, 1976.

11. Pearson, Major John M., USAF. Department of Quantitative Managemgent, Air Force Institute of Technology, School of Systems and Logistics, Wright-Patterson AFB OH. Personal interview. 7 April 1977.

12. Pritsker, A. Alan B., and Phillip J. Kiviat. Simulation with GASP II. Englewood Cliffs NJ: Prentice-Hall, Inc., 1969.

13. Rippy, Major Douglas P., USAF. Plans and Programs Division, HQ AFLC, Wright-Patterson AFB OH. Personal interview. 14 December 1976.

14. Sherbrooke, Craig C. "METRIC: A Multi-Echelon Technique for Recoverable Item Control." Unpublished research report No. RM-5078-PR, RAND Corporation, Santa Monica CA, 1966.

15. U.S. Department of the Air Force. Equipment Maintenance Policies, Objectives, and Responsibilities. AFR 66-14. Washington: Government Printing Office, 1975.

16. Wood, Chief Master Sergeant Billy J., USAF. SAC Liaison to B-1 SPO, Aerospace Systems Division, ASD, Wright-Patterson AFB OH. Personal interview. 6 January 1977.

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