THE ONTARIO WALL DRYING PROJECT

PHASE 2

prepared for

CANADA MORTGAGE AND HOUSING CORPORATION

E. F. P. BURNETT

MARCH 1993

Canada Mortgage and Housing Corporation (CMHC), the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, CMHC has interests in all aspects of housing and urban growth and development.

Under Part IX of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of the many items of information published by CMHC with the assistance of federal funds. The views expressed are those of the author(s) and do not necessarily represent the official views of Canada Mortgage and Housing Corporation.

SUMMARY

Over a 24-month period spanning 1989/90/91, a study of the drying performance of various wall systems was carried out by the Building Engineering Group. The primary objective was to obtain a broader and better understanding of the moisture-related performance of various house wall assemblies constructed with wet/green (above 19% moisture content) framing lumber. This project, formally designated the Ontario Wall Drying Project, was conducted under the direction of an Advisory Committee representing the various sponsoring organizations. In June 1991 a detailed report, *The Ontario Wall Drying Project*, was completed and has since been issued by CMHC.

Early in 1991 consideration was given to the likely variation in wood moisture content over the longer term for different wall systems under normal operating conditions. Additional questions concerned the influence of orientation, external sheathing, and the possibility of wetting as a result of relatively high humidity levels within the test facility. Since the full-scale test panels had reached equilibrium levels for moisture content, any subsequent variation would be due largely to seasonal variations. For these reasons it was decided to extend the project. CMHC provided the funds to undertake Phase 2.

The primary objective in the second phase was to monitor and assess wall system performance over at least one winter, one swing period(spring or fall), and one summer. As in Phase I, variation in the moisture content in the framing lumber was of primary concern.

This second phase of a three-year study has demonstrated quite clearly that by the third year all the wood had dried down to base equilibrium levels of about 13% or less. Equilibrium wood-moisture-content values of between 10% and 13% seem to be consistent with the nature of southwestern Ontario's climate.

The seasonal variation in equilibrium levels of wood-moisture content is relatively small and, in most instances, there is little evidence of any significant adjustment in equilibrium moisture content due to seasonal change. The onset of warm weather can result in an increase in wood moisture content of 2% to 3%. The extent of this warm weather increment will depend upon the moisture content. For moisture contents of 13% or less, this variation should not have any significant influence on performance. Drying and wetting depend upon the potential for moisture movement due to air flow and water vapour diffusion. It follows that the drying process can slow down and even be reversed. In none of the test panels, however, did this phenomenon have any significant impact on the overall performance of the wall system.

RÉSUMÉ

Pendant 24 mois, entre 1989 et 1991, une recherche sur l'assèchement de divers types de murs a été menée par le Groupe de génie en construction en vue d'obtenir une connaissance meilleure et plus large de la tenue en service de murs construits en bois de charpente vert ou humide (d'une teneur en eau supérieure à 19 p. 100). Cette recherche, officiellement connue sous le nom de The Ontario Wall Drying Project, a été effectuée sous la direction d'un comité consultatif représentant divers organismes. Au mois de juin 1991, un rapport détaillé, appelé «The Ontario Wall Drying Project, était achevé pour ensuite être publié par la SCHL.

Au début de 1991, les chercheurs ont envisagé la probabilité que la teneur en eau du bois varie avec le temps, dans des conditions normales, pour différents types de murs. D'autres questions avaient trait à l'effet de l'orientation et du revêtement d'ossature extérieur ainsi qu'à la possibilité d'humidification à cause du taux d'humidité relativement élevé régnant à l'intérieur de l'installation d'essai. Comme la teneur en eau des panneaux d'essai en vraie grandeur avait atteint un état d'équilibre relatif, tout changement subséquent serait largement le fait de variations saisonnières. C'est pourquoi les responsables de la recherche ont décidé de prolonger cette dernière, et la SCHL a fourni les fonds nécessaires au lancement de la phase 2.

La phase 2 avait pour but de contrôler et d'évaluer le comportement des murs durant au moins un hiver, un automne ou un printemps et un été. Comme pour la phase 1, la variation de la teneur en eau du bois de construction constituait la principale préoccupation.

Cette seconde phase d'une étude de trois ans a démontré très clairement que, la troisième année, tout le bois avait séché au point d'atteindre un niveau d'équilibre à un taux d'environ 13 p. 100 ou moins. Des teneurs en eau à un niveau d'équilibre se situant entre 10 et 13 p. 100 semblent correspondre à la nature du climat du sud-ouest de l'Ontario.

La variation saisonnière des niveaux d'équilibre de la teneur en eau du bois est peu importante et, dans la plupart des cas, ces niveaux ne varient pas vraiment avec les saisons. L'arrivée de temps chaud peut cependant provoquer une augmentation de 2 à 3 p. 100 de la teneur en eau, l'ampleur de cette augmentation dépendant de la teneur en eau. Lorsque celle-ci est de 13 p. 100 ou moins, l'écart ne devrait pas modifier le comportement des murs. L'assèchement et l'humidification sont tributaires du potentiel de mouvement de l'humidité qu'entraîne le mouvement d'air et de la diffusion de la vapeur d'eau. Il s'ensuit que le processus d'assèchement peut être ralenti et même inversé. Toutefois, ce phénomène n'a pas eu d'effet significatif sur le comportement global des panneaux à l'essai.

CMHC SCHL
Helping to house Canadians
Question habitation, comptez sur nous

National Office
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Bureau National
700 chemin Montréal
Ottawa (Ontario)
K1A 0P7

Puisqu'on prévoit une demande restreinte pour ce document de recherche, seul le sommaire a été traduit.

La SCHL fera traduire le document si la demande le justifie.

Pour nous aider à déterminer si la demande justifie que ce rapport soit traduit en français, veuillez remplir la partie ci-dessous et la retourner à l'adresse suivante :

Le Centre canadien de documentation sur l'habitation
La Société canadienne d'hypothèques et de logement
700, chemin de Montréal, bureau C1-200
Ottawa (Ontario)
K1A 0P7

TITRE DU RAPPORT : ______________________________

____

Je préférerais que ce rapport soit disponible en français.

NOM ______________________________

ADRESSE ______________________________
rue app.

____
ville province code postal

No de télephone ( ) ____________

ACKNOWLEDGEMENTS

The impetus for doing the Ontario Wall Drying Project came from the Canada Mortgage and Housing Corporation. CMHC provided the initial seed funding for Phase 1 and the supplementary funds to conduct Phase 2. Tom Kerwin of the Housing Innovation

Division provided interested and competent leadership in administering the project. We gratefully acknowledge the support of CMHC and the assistance provided by Tom Kerwin.

The detailed feedback provided by Amanda Reynolds of Scanada Consultants and Don Onysko of Forintek was of great value. The willing and able assistance of both Peter Sloof and John Straube in collecting, manipulating and presenting data was also much appreciated.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 BACKGROUND

Over a 24-month period spanning 1989/90/91, a study of the drying performance of various wall systems was carried out by the Building Engineering Group. The primary objective was to obtain a broader and better understanding of the moisture-related performance of various house wall assemblies constructed with wet/green (above 19 % moisture content) framing lumber.

This project, formally designated the Ontario Wall Drying Project, was conducted under the direction of an Advisory Committee representing the following organizations:

- Ontario Home Builders Association (OHBA)
- Canada Mortgage and Housing Corporation (CMHC)
- Ontario New Home Warranty Program (ONHWP)
- The Society for the Plastics Industry of Canada (SPI)
- The Structural Board Association
- Canadian Fibreboard Manufacturers Association
- Canadian Association of Man-Made Mineral Fibre Manufacturers (CAMMMFM)
- Forintek Canada Corporation
- Building Engineering Group, University of Waterloo

The experimental work for this research, development and demonstration (R, D and D) project was conducted using the full-scale test facility (BEGHUT) at the University of Waterloo. Using framing lumber that had been pre-conditioned to moisture contents well in excess of 19%, twelve pairs of 1200mm x 2400mm test panels were constructed. Pairs of panels were located either north and south or east and west on the four sides of the test facility. Ten different wall systems were tested. The principal construction variables were:

- 2 x 4 and 2 x 6 framing

- sheathing material:
  - insulating (glass-fibre board, extruded polystyrene and polyisocyanurate)
  - non-insulating (waferboard, fibreboard, gypsum board)

- cladding—vinyl and brick masonry

- orientation

Each panel was instrumented to measure wood moisture content, temperature, and relative humidity at strategic locations. The panels were installed in December 1989 and monitored continuously for 11 months. The interior environment was maintained at about 20°C and 50% relative humidity. Supplementary testing for air leakage and microbiological activity was also conducted.

In June 1991 a detailed report, *The Ontario Wall Drying Project*, was completed and has since been issued by CMHC. The report describes the test program, and the recording and analysis of the results and draws some general conclusions. Details of calibration, moisture-content measurements and other experimental results, and microbiological and air-leakage test results are documented in appendices to the report.

Early in 1991 some consideration was given to the likely variation in wood moisture content over the longer term for different wall systems under normal operating conditions. Additional questions concerned the influence of orientation, external sheathing, and the possibility of wetting as a result of relatively high humidity levels within the test facility. Since the full-scale test panels had reached equilibrium levels for moisture content, any subsequent variation would be due largely to seasonal variations. Because the test panels and all the relevant instrumentation were already in place and because it was only really a question of continuing with the project, the Advisory Committee encouraged CMHC to provide the support for a second phase to the Ontario Wall Drying Project.

It needs to be noted that Phase 1 of *The Ontario Wall Drying Project* was one of three complementary, field moisture studies initiated by CMHC. The first study was conducted in the Atlantic region over the period 1985-1988. The other project was carried out in Alberta in 1989-1990. The final reports for these three projects, as well as that for this Phase 2 study, are available from CMHC.

1.2 OBJECTIVES

The primary objective in the second phase of the project was to monitor and assess wall system performance over at least one winter, one swing period(spring or fall), and one summer. As in Phase I, variation in the moisture content in the framing lumber was of primary concern. In general, the intent was to continue monitoring the 24 wall panels subject to a maintained interior microclimate (20°C, 50% R.H.) and the weather that prevails in Southwestern Ontario.

1.3 SCOPE

The physical scope of the project was precisely the same as that in Phase 1. The time frame for the second phase was as follows:

Phase 2, period 2A: involved all of the original twelve pairs of wall panels and required continuous monitoring over the period November 16, 1990, to July 15, 1991. Over the summer and fall of 1991, 12 wall panels (six pairs) were replaced as three new projects were introduced into BEGHUT.

Phase 2, period 2B: involved the monitoring of six pairs of panels over the period November 1, 1991 to August 15, 1992. The overall time-frame for both phases of this work is shown in Figure 1.1. Although only six pairs of panels were involved in the 2B time period, this extension of the initial scope of the Phase 2 project added significantly to the value of the project.

1.4 APPROACH

Since November 16, 1990, a great deal of data has been collected. Some 400 data channels have been continuously monitored, and hourly averages have been stored on disk. Moreover, some ten different wall systems are involved. The final report on Phase 1 of this project documents in considerable detail the test facility, the test panels, the test set-up, the nature and location of all instrumentation, all data protocols, data acquisition and storage and related details. Accordingly, the information is not repeated in this Phase 2 report. (This second report is intended to be a companion to the previous report.) The Phase 2 report is limited to an assessment of the data collected. The data, in graphical form, is contained in nine appendices (Appendix A to Appendix I) that cover nearly three years of monitoring.

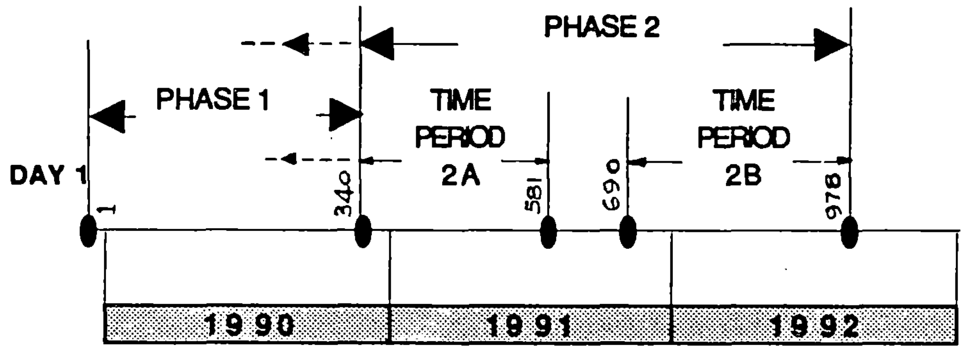


FIGURE 1.1: PHASE 1 AND PHASE 2 –TIME PERIODS 2A AND 2B

2. TEST SET-UP AND PROCEDURE

2.1 TEST PANELS

Details of all the test panels are provided in Table 2.1. Their location in the test facility (BEGHUT) is shown in Figure 2.1.

2.2 MONITORING CONDITIONS

Both the interior micro-climate and exterior weather conditions—in particular, temperature and relative humidity—were continuously monitored. The weather station is above the apex of the roof of BEGHUT, at a height of 10 m. above the ground. Wind speed and direction were also measured. These wind records are not documented here, but it needs to be emphasized that the prevailing daily average wind is from a direction 60 degrees west of North.

In each panel at least 6 temperatures, 6 moisture contents, and 2 relative humidities were monitored. Monitoring was continuous with the following exceptions :

- The three-month period between time periods 2A and 2B. During the Fall of 1991 six pairs of wall panels—N1 &S1, N2 & S2, N3 & S3, E4 & W4, E5 & W5, E6 & W6—were dismantled, examined and removed. They were then replaced with panels for projects funded by CMHC, IRC/NRC, and private industry. During this period major improvements were made to the space-conditioning system, and this was the main reason for the delay.

- Over the period February to April 1991, some serious problems were experienced with the data acquisition system (both hardware and software) and monitoring had to be stopped.

- Short periods when either by default (caused by a power surge, over-ranging or lightning) or by intent (for maintenance, other testing, etc.), scanning was stopped.

It was largely to compensate for these interruptions that it was decided to continue monitoring well into 1992. The time period 2B is also the better period in which to assess seasonal wood moisture variations—not only because a winter, a swing season(the spring period) and a summer are included but also because it is a later period and therefore less affected by the built-in wetting during Phase 1.

TABLE 2.1 - DETAILS OF WALL ASSEMBLIES

PANEL	FRAMING	SHEATHING	EXTERIOR
N1-S1	2" X 6"	1/2" gypsum board[4]	-building paper -vinyl siding
N2-S2	2" X 6"	7/16" fibreboard	-building paper -vinyl siding
N3-S3	2" X 6"	7/16" waferboard	-building paper -vinyl siding
N4-S4	2" X 4"	1 1/2" semi-rigid glass fibre insulation board with spun-bonded polyolefin	-taped joints -vinyl siding
N5-S5	2" X 4"	1 1/2" type 4 extruded poly-styrene (EXPS), shiplapped and butted	-building paper -vinyl siding
N6-S6	2" X 4"	1" trilaminate polyisocyanurate, butted	-building paper -vinyl siding
E1-W1	2" X 4"	1 1/2" semi-rigid glass fibre insulation board with spun-bonded polyolefin	-taped joints -clay brick
E2-W2	2" X 4"	7/16" fibreboard	-building paper -clay brick
E3-W3	2" X 4"	7/16" waferboard	-building paper -clay brick
E4-W4	2" X 4"	1 1/2" semi-rigid glass fibre insulation board with spun-bonded polyolefin	-taped joints -vinyl siding
E5-W5	2" X 4"	1 1/2" type 4 EXPS, shiplapped and butted	-building paper -clay brick
E6-W6	2" X 4" (delayed closing)	1 1/2" type 4 EXPS, shiplapped and butted	-building paper -clay brick

NOTES:

1. Fibrous glass batt insulation was friction fitted within the stud space (RSI 2.1 within the 2x4 construction and RSI 3.5 within the 2x6 construction).
2. Nominal imperial dimensions have been used in this table largely because this is how the materials are identified in the trade literature. For the record, 2x4 lumber is equivalent to 38mm x 89mm; 2x6 lumber is equivalent to 38mm x 140mm; 1/2" is equivalent to 13mm; 1" is equivalent to 25mm; 7/16" is equivalent to 11mm; 1.5" is equivalent to 38mm.
3. All panels are sealed to the interior with 6 mil polyethylene and covered with 13mm (1/2") gypsum wallboard.
4. This sheathing was intended to be an exerior grade gypsum "sheathing" product. In fact, an interior grade gypsum lath product was installed.

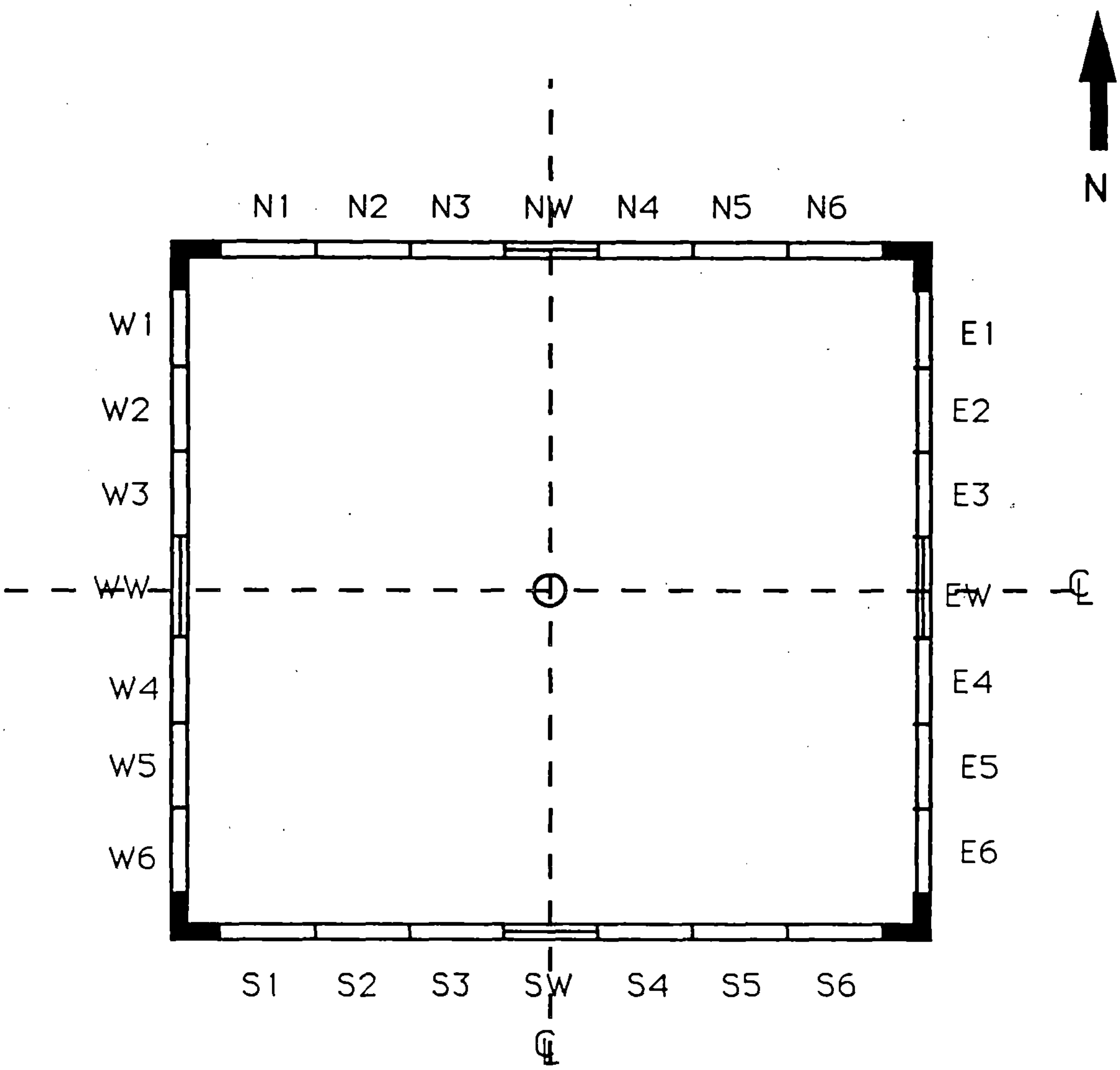


Figure 2.1 - PANEL LOCATION AND CODING

2.3 INTERIOR CONDITIONS

The average daily indoor temperature was, subject to minor variation, maintained between 20 and 21°C. The average daily relative humidity was maintained at 50%. During 1992 any variations in interior conditions were relatively small. Relevant data on interior conditions are recorded in Appendix A.

2.4 EXTERIOR CONDITIONS

Records of daily average values of temperature and relative humidity are provided. Note that the summer of 1992 was relatively cool and wet and that there were significant differences in the weather over the two time periods 2A and 2B. Relevant data on exterior conditions are recorded in Appendix A.

3. TEST RESULTS

3.1 WALL-SYSTEM TEST PANELS

The distribution, composition and location of all instrumentation are shown in Figure 3.1. As was done in Phase 1, the test results from panels E5 (excessive wetting), N1 and S1(gypsum lath), and N3 and S3 (balsam fir studs) are not reported or discussed. The reasons for excluding these panels are given in the Phase 1 report.

3.2 WOOD-MOISTURE CONTENT

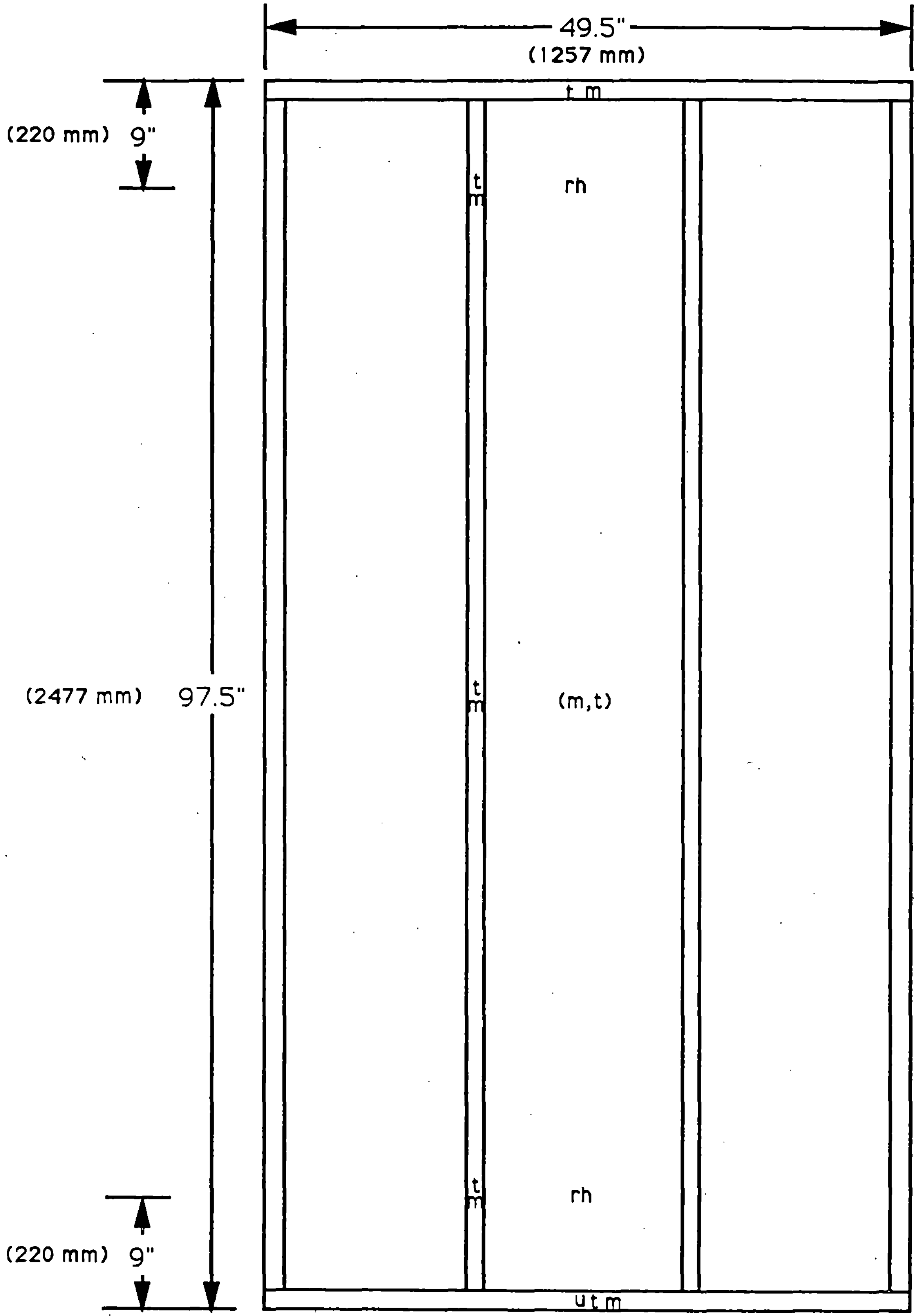
3.2.1 Operating Conditions

In this Phase 2 project, the primary interest was tracking the moisture-related performance of the wood framing starting from an initial equilibrium condition. Accordingly the actual starting point for this Phase 2 study occured sometime in the spring or summer of 1990; this starting date varied from panel to panel. At that point, the excess built-in moisture in the wood had been given up and an equilibrium moisture content had been reached; that is, the wood and the surrounding environment were in balance insofar as moisture is concerned. Although the framing lumber may have dried, it should be remembered that this moisture may still have been within the wall system. As shown in Figure 3.2, moisture in one or more forms may be trapped at—or in transit across—other locations in the wall. Therefore any change in the wood-moisture content during Phase 2 was due to:

i) moisture from the interior as either water vapour or air leakage. The former was negligible and the latter probably very small, since the 6 mil poly vapour retarder was well sealed at the edges. The effectiveness of the vapour retarder and air barrier was confirmed by the constancy of results in the third year.

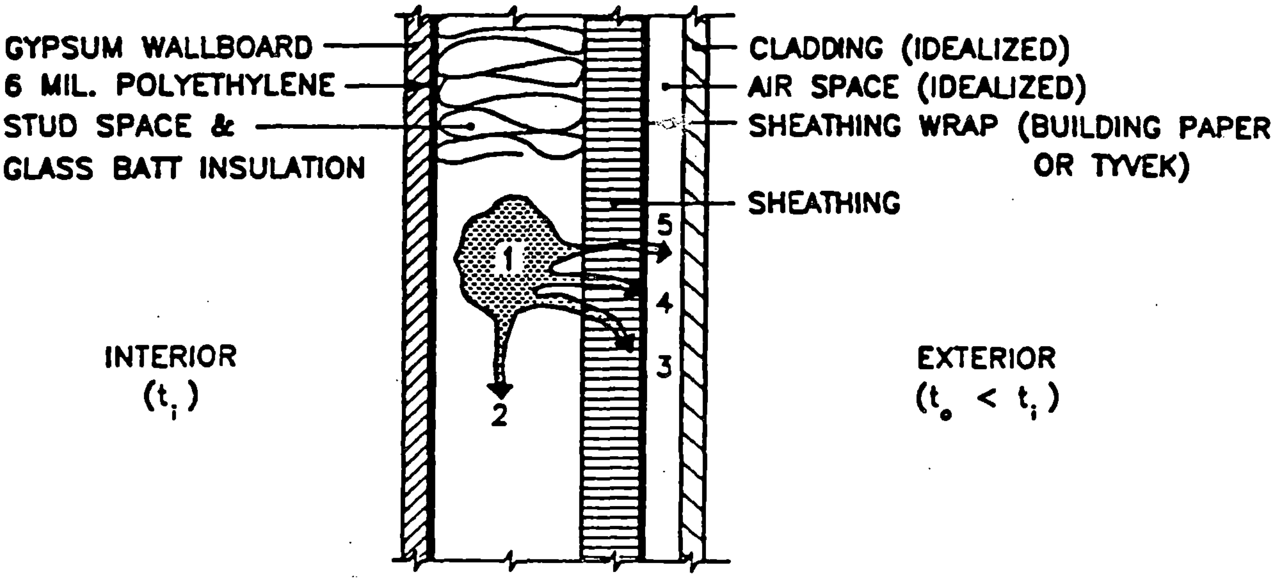
ii) moisture from within the wall system. Given that some of the initial built-in wood moisture might have been stored in the sheathing (particularly the non-insulating sheathings, such as waferboard and fibreboard) or elsewhere within the wall panel, there might have been a reversal of moisture transference with the onset of warm weather. Convective air flow might have been responsible for some moisture transfer in the vertical direction.

iii) moisture ingress from outside, e.g., inward water vapour diffusion in summer, wetting due to rain penetration, etc.



t - thermocouple
m - moisture content pins
u - uninsulated moisture content pins
rh - relative humidity gauge
( ) - indicates in wood-based sheathings only

FIGURE 3.1 - LOCATION OF GAUGES IN ALL PANELS



LEGEND:
1. MOISTURE GIVEN UP BY WOOD.
2. PROPORTION OF MOISTURE IN STUD SPACE.
3. PROPORTION OF MOISTURE ON OR WITHIN SHEATHING.
4. PROPORTION OF MOISTURE ON INNER FACE OF SHEATHING WRAP OR BUILDING PAPER.
5. PROPORTION OF MOISTURE TRANSMITTED BEYOND SHEATHING WRAP TO BE STORED, DRAINED VENTED OR OTHERWISE REMOVED.

FIGURE 3.2: CONSTRUCTION MOISTURE CONSIDERATIONS

The measurement of wood moisture content, especially at the extremes, is not necessarily an exact science. Accordingly, the following limitations apply:

- Values less than 8% were disregarded. Low moisture contents involve low levels of electrical conductivity, and over-ranging (off-scale values) occurred in the instrumentation.

- As the determination of wood moisture content is dependent upon both wood species and temperature, it follows that, for different types of woods and at different locations, the minimum recordable value that is accurate will vary. Values of about 10 per cent or less should, therefore, be treated with some caution—especially if there is no variation in value.

- At low levels the relative value and the variation in value of the moisture contents are probably of greater significance than the absolute numerical values that are determined.

A discussion of the overall performance of sets of panels follows. The emphasis is on seasonal effects on wood-moisture content, but thermal and relative humidity considerations are also examined.

3.3 PANELS WITH SEMI-RIGID GLASS FIBRE INSULATION BOARD WITH ADHERED SPUN-BONDED POLYOLEFIN

3.3.1 Panels N4, S4, E4 and W4 (with vinyl siding)—Appendix B

With the exception of the bottom plate, the moisture content of the framing lumber (the monitored vertical stud and the top plate) in these panels remained relatively constant. Values ranged between 9% and 12% in time period 2A and between 11 and 13% over period 2B. There is no evidence to suggest that there is any consistent variation in equilibrium moisture content as a consequence of seasonal variations.

Over the 1991-1992 time period 2B, the mean wood moisture content in each panel was, on average, slightly higher than over the time period 2A in 1990-1991 -- see Figure 1.1. Given the nature of the experiment, this difference is not considered to be statistically significant. Nonetheless this effect might have something to do with the fact that:

- the weather in 1992, particularly over the summer, was generally cooler, and

- the mean RH of the interior environment (the test hut) was higher in 1992 compared to 1991.

The lower wall plate was consistently cooler than other elements of the framing lumber. This thermal difference was greatest on the west side, which is the direction of the prevailing wind. Furthermore, the RH within the lower part of the stud space was generally higher than that in the upper part. Both these factors might have influenced the tendency of the moisture content of the bottom plate to increase and to vary relative to other elements of the wood framing.

One aspect of both the bottom and the top plates in these panels that was not quite consistent with practice was the fact that the sheathing covered only half the height of the wood, as shown in Figure 3.3b. It follows that each side of the bottom half of the bottom plate were exposed in a slightly different manner to the interior and exterior environments. This may account for the consistently lower temperature recorded in the bottom plate and hence the more variable and higher moisture contents.

Each of these four identical panels faced a cardinal compass direction. These four panels represent the only one of the test wall systems to be oriented in four different directions, and it is of interest to identify any well-defined influence from orientation. Mean daily wood temperatures on the north face were all generally cooler (by as much as 5°C) than the daily average values recorded in the other three directions, which were generally similar to each other. The prevailing winds were from the west (W30°N). This effect is noticeable in that:

- on the west face the lower temperature values were often lower than on the south and east faces, and
- the lower or bottom plate was coldest on the west side.

Clearly, the wind does influence the state of the lower plate.

Also, in those panels with vinyl siding, the lack of direct solar radiation on the north side had a significant effect on the internal thermal environment. Orientation, or more specifically the prevailing wind, also had an influence on RH within the stud space. On the north and particularly the west-facing panels, these mean daily RH values were more attenuated and generally lower than on the south and east faces, which were in the lee of the prevailing wind.

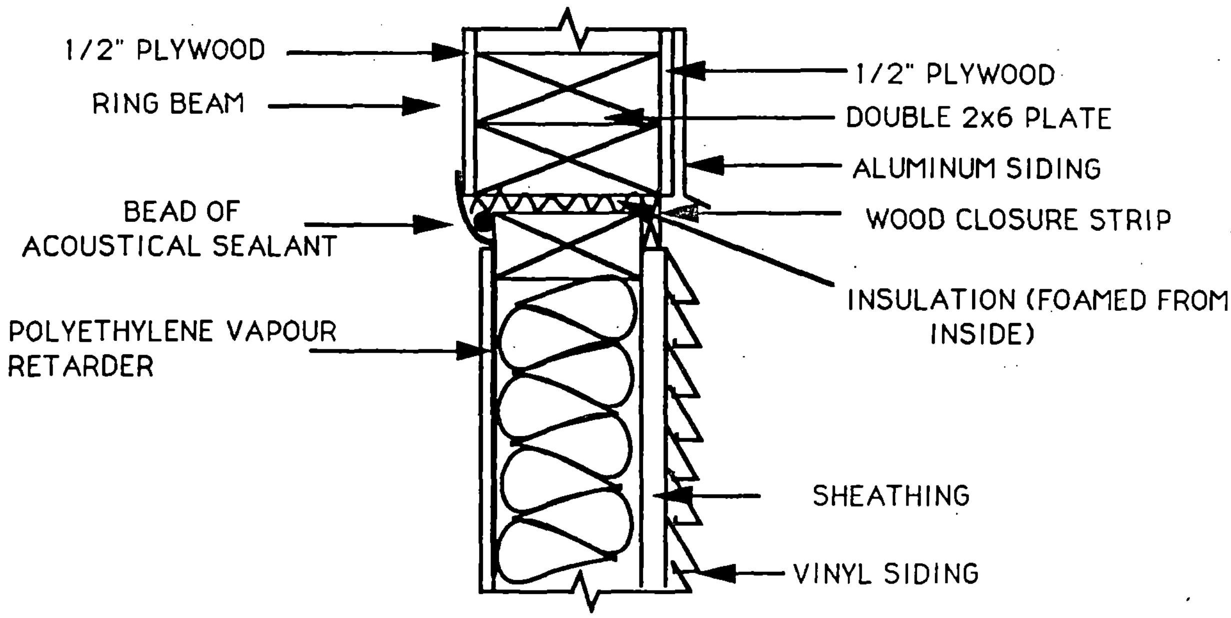


FIGURE 3.3a - TOP PLATE CONSTRUCTION DETAIL

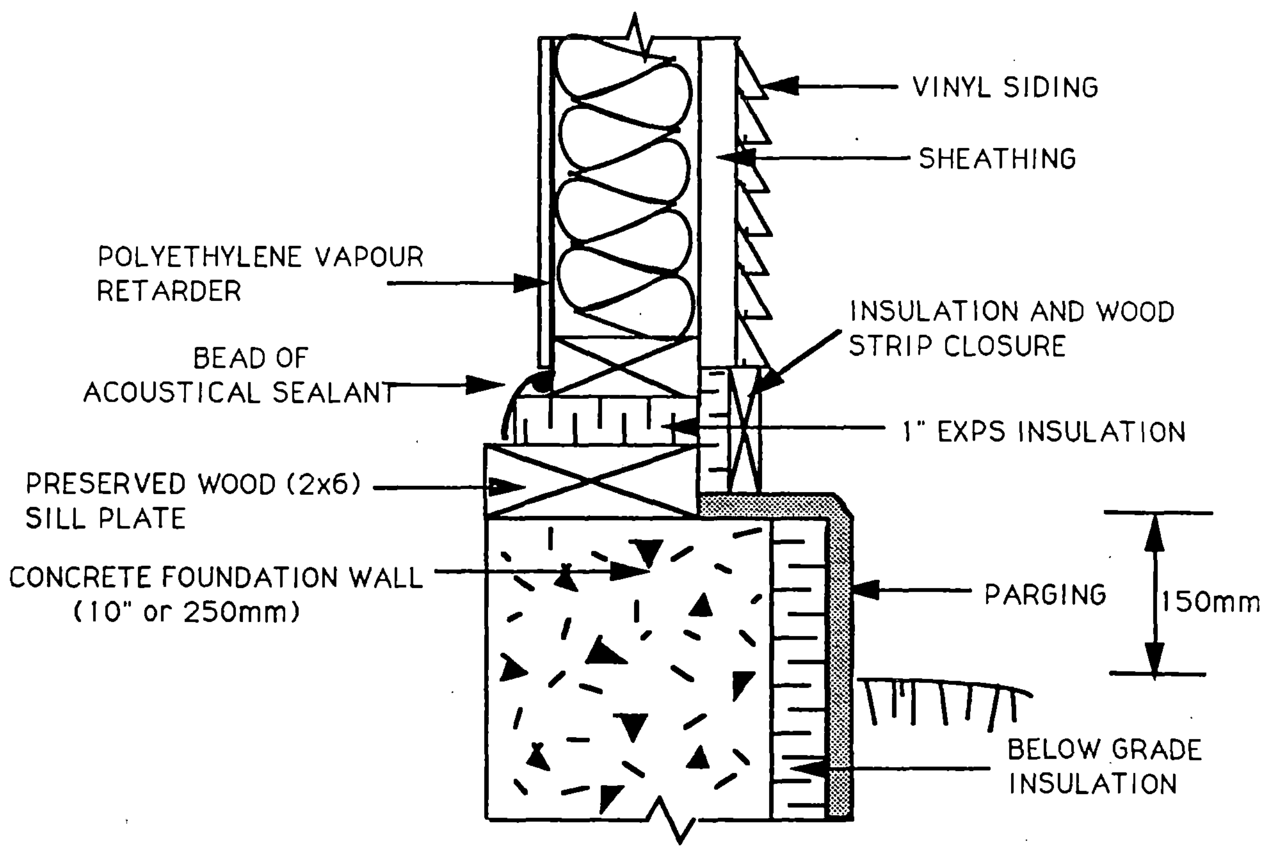


FIGURE 3.3.b - BOTTOM PLATE CONSTRUCTION DETAIL

3.3.2 Panels E1 and W1 (brick veneer instead of vinyl siding)Appendix C

The equilibrium moisture content in both these panels did tend to vary slightly with time, but only in panel W1 was there any evidence to suggest that the equilibrium values were affected by the weather. In W1 over period 2A, the equilibrium moisture content values appear to have been 1% to 2% higher over the colder months. This trend was slight and not evident in period 2B.

As noted with other test panels, the bottom plates tended to have higher equilibrium moisture content values than the vertical studs and top plates. The relative difference decreased with time, and over the time period 2B it could be said that all the framing lumber settled down to similar if not the same moisture content. Any slight overall variation could have been due to seasonal effects, but for all practical purposes the wood moisture content in panels E1 and W1 had, after two years, stabilized at between 10 and 15%.

The bottom plates in both panels were consistently at a lower temperature than other framing elements and, largely because of the prevailing wind, the mean daily temperature of the bottom plate in the W1 panel was generally lower than that in the E1 panel. Relative humidity values in both panels followed similar patterns, with the values in the west panel, W1, tending to be more attenuated and generally (but not consistently) higher than the values in the E1 panel.

3.4 PANELS WITH TYPE 4 EXTRUDED POLYSTYRENE SHEATHING AND BUILDING PAPER

3.4.1 Panels N5 and S5 (with vinyl siding)—Appendix D

The insulating sheathing in these panels consisted of 11/2 inch thick (38mm) board with shiplapped edges. This sheathing was covered with building paper. The insulating material has a relatively high resistance to vapour flow (low permeability) and, if properly assembled, is relatively airtight. That these properties had an influence on the rate of wood drying is clearly evident from the figures showing the variation in wood moisture content with time.

For both panels N5 and S5 it was evident that the wood drying process had slowed and even reversed. This phenomenon—also clearly evident in panel S6—is neither unexpected nor unusual, but it is a function of the wood moisture content and the weather. For example, in those panels where some levels of wood moisture content were still relatively high, the arrival of warmer weather in 1990 caused the vapour pressure difference across the wall to decrease and, later, to reverse. With warm weather the insulation and building paper were also likely to be in their most airtight mode. This warm-weather effect is not peculiar to these panels. Nearly all the test panels exhibited some tendency to develop higher equilibrium moisture contents in the summer of 1992.

With the coming of cold weather in December 1991, additional outward moisture movement and drying occurred, and all the framing lumber in panels N5 and S5 reached base equilibrium moisture content levels of less than 14%. Note that even after two years the onset of hot weather (June and July) tended to increase the wood moisture content values slightly.

The N5 panel was consistently colder than the S5 panel. Moreover, during the winter, the vinyl siding and the cavity behind it, especially on the north side, spent long periods of time at below-freezing temperatures. This would have inhibited drying. In addition, the relative humidity levels in the stud space, especially that in the north-facing panel, were consistently much higher than in other panels—N4 and S4, for instance. This effect diminished with time, and after three years it would seem that RH levels were converging to similar levels.

3.4.2 Panels E6, W6 and W5 (with brick veneer)—Appendix E

Panels E6, W6 and W5 were not monitored over time period 2B. But, over the nearly two years that these panels were monitored, their performance tended to confirm the conclusions made on the basis of the performance of panels N5 and S5. In particular, if the framing lumber has not dried down to base levels of about 13%, then, as the weather warms up, there will be a slowing down and, in some instances, a reversal of the drying process. Later, as the weather cools, the drying process resumes and eventually (after one year for E6 and even in the case of panel E5, which suffered some rain penetration, after 14 months) a base equilibrium moisture content is attained.

The fact that a base equilibrium moisture content was attained is an important conclusion, and it emphasizes the relevance of timing, i.e., speed of construction and time of year, and the nature of subsequent drying. In general, wood drying and the drying of moisture from the wall system is accelerated in winter and can be slowed down and even reversed in the summer, especially with a combination of prolonged warm weather and interior cooling. The length of the overall drying period is therefore dependent not only upon the nature of the assembly and the amount of wood moisture, but also upon the time of closure and operation of the building.

It is interesting to compare the performance of these brick-clad panels with the vinyl-clad pair of panels, N5 and S5. In spite of the differences in orientation, the wood drying performance of the brick-clad panels seems to have been marginally better than that of the vinyl cladding panels. This difference was probably because the thermal environment within the stud space was slightly higher with brick veneer. The difference in thermal conditions was probably also one reason why the relative humidity levels within the stud space were significantly lower in the brick-clad panels (E6, W6, and W5) compared to the vinyl-clad panels (N5 and S5). Another reason was that the building paper performed much better as an air barrier with a vinyl siding than with a cavity and brick veneer; the air leakage characteristics of the building paper are affected by the cladding and its attachment as well as orientation. In the initial report, pressurization-air-leakage testing confirmed that the prevailing wind can adversely influence the air-leakage characteristics of a brick-veneer-clad wall system.

One other point to note is that with brick veneer, the temperature of the bottom plate seems to be slightly cooler than when vinyl cladding is used. This difference may be due to the presence of weep holes at the base of the brick veneer and the infiltration of air.

3.5 PANELS WITH 1" (25 MM.) THICK TRILAMINATE POLYISOCYANURATE, BUTT-JOINTED SHEATHING WITH BUILDING PAPER AND VINYL SIDING (N6 AND S6)—APPENDIX F

The foil-faced trilaminate facing on both sides of the insulation renders this insulating sheathing essentially impermeable to air, moisture, and moisture-vapour flow. System drying, which demonstrably occurred, must necessarily be by means of air leakage at the joints. The rate and nature of wood drying was affected by the sheathing. The similarity between the performance of the panels with extruded polystyrene sheathing (panels N5 and S5) and the panels N6 and S6 should be noted.

As the moisture-content versus time figures demonstrate, the manner in which the wood framing reached a base equilibrium level of about 11% was dependent upon timing (the time of installation and the moisture content at that time). The panels N6 and S6 were assembled in December 1989 and underwent fairly rapid drying, but drying was arrested and even reversed with the onset of the warm weather. In both panels, drying down to the base equilibrium level of 10 or 11% took about 14 months. To a lesser degree, the seasonal tendency for winter drying and summer wetting to occur was evident over the time period 2B.

Note that the wood temperatures in the N6 and S6 panels were very slightly higher than in the N5 and S5 pair, reflecting the slightly higher R value and the reflective film on the outer face of the sheathing in the N6 and S6 panels. It is significant that the N6 and S6 panels had relative humidity levels within their stud spaces that were consistently higher than those in the N5, S5 panels. Combined with the higher temperatures, a higher RH means that more moisture was being maintained within the stud space of the N6/S6 panels.

3.6 PANELS WITH FIBREBOARD SHEATHING

3.6.1 N2 and S2 (with 2 x 6 framing, building paper and vinyl siding)—Appendix G

Those panels with non-insulating sheathing (fibreboard and waferboard) exhibited wood-drying tendencies somewhat different from the panels with insulating sheathings. Both waferboard and fibreboard sheathings have large surface areas and nearly as much volume as the framing lumber. These sheathings are essentially receivers, accumulators and transmitters of moisture in all its physical states, i.e., frost, water, or water vapour. It follows that the actual mechanics of moisture movement within and out of these test panels must have been different from those panels with insulating sheathings.

In N2 and S2, the wood framing dried down to low levels, less than 13%, fairly rapidly. Subsequent changes in the weather induced change in water vapour and air pressure differentials. Accordingly, the fact that the moisture content of the sheathing was raised and stayed relatively high could have affected the moisture content levels in the framing lumber. In N2, the moisture content in the framing lumber seemed to get 1% to 3% higher with warmer weather and then dried down again with the onset of cooler weather. Panel S2 seemed to do the opposite, but this may have been due to the effects of solar radiation on this south-facing, vinyl clad panel with a non-insulating sheathing. Wood temperature levels were generally higher in S2 than in N2 and this does influence the distribution of moisture within the panel.

The difference in response between panels N2 and S2 is reflected in the figures showing the variation in relative humidity in the stud space. The RH levels in S2 were substantially lower than in N2, suggesting that nature of moisture movement may have been different in the two panels. It is possible that S2 had the benefit of south-facing solar radiation and air exfiltration because it was on the leeward side. The north panel was, in general, under infiltration due to wind and received no direct solar radiation. Both these factors can be significant with a vinyl or other contact attached facade.

3.6.2 E2 and W2 (with 2x4 framing, building paper and brick veneer)—Appendix H

Both the E2 and W2 panels exhibited a small degree of variation in moisture content with the onset of warm weather. This behaviour was clearly evident for the time period 2A but was less pronounced over period 2B. The difference between the wood moisture levels in periods 2A and 2B was probably due to two factors. First, there is likely to have been much more moisture in the wall system (within the board sheathing) over the earlier period. Second, the weather during time period 2B was relatively cool, dull and wet. While there may have been some seasonal impact on equilibrium wood measure levels, this was not quantitatively or otherwise significant.

The mean daily temperatures for the framing lumber in both panels E2 and W2 were greater than those for both panels N2 and S2. In spite of the fact that the former pair had 2x4 studs and the latter pair 2x6 studs, the panels with brick veneer generally provided a warmer thermal environment within the stud space than did those with a vinyl siding—or, for that matter, other contact-applied sidings. Even the panel on the south side (S2) with vinyl siding had lower mean daily temperatures within the stud space than either the east or west-facing brick veneer panels (E2 and W2).

3.7 PANELS WITH FIBREBOARD SHEATHING - E3 AND W3 (WITH 2X4 FRAMING, BUILDING PAPER AND BRICK VENEER)—APPENDIX I

In terms of wood moisture content and the Phase 2 time periods, the pair of panels E3 and W3 performed in a manner that was essentially the same as E2 and W2. Any general variation in equilibrium wood moisture content due to seasonal change was not significant; at least the quality of the data did not warrant a quantitative conclusion. By the third year, for time period 2B, there was little variation. There was some evidence of higher moisture content with warm weather, but again this was neither significant nor unexpected for this wall system.

There is little difference in the performance of the panels with waferboard sheathing (E3 and W3) compared with that for the panels with fibreboard sheathing (E2 and W2). Differences are evident in the graphs of moisture content, wood temperature and stud space relative humidity, but they are not consistent or statistically significant given the nature of this experiment.

4. CONCLUSIONS AND RECOMMENDATIONS

The seasonal variation in equilibrium levels of wood-moisture content is relatively small and, in most instances, there is little evidence of any significant adjustment in equilibrium moisture content due to seasonal change. These conclusions are, however, subject to two conditions:

- drying of built-in moisture must have occurred and the wood moisture content should be well below 19%, and
- a good vapour retarder/air barrier on the warm side of the stud space must have been used.

On the other hand, there is clear evidence that timing is an important consideration, i.e., when closure occurs and how much drying has taken place by the time warm weather commences. Clearly, the onset of warm weather can result in an increase in wood moisture content of 2 to 3% or more. The extent of this warm weather increment will depend upon the moisture content. For moisture contents of 13% or less this variation should not have any significant influence on performance. Drying and, for that matter, wetting depends upon the potential for moisture movement due to air flow and water vapour diffusion. It follows that the drying process can slow down and even be reversed. In none of the test panels did this phenomenon have any significant impact on the overall performance of the wall system.

Another timing-related consideration involves the installation of the sheathing. In particular, those sheathings with low water vapour permeability need to be installed in such a manner that any potential for winter drying is enhanced. This is particularly important for built-in moisture loads.

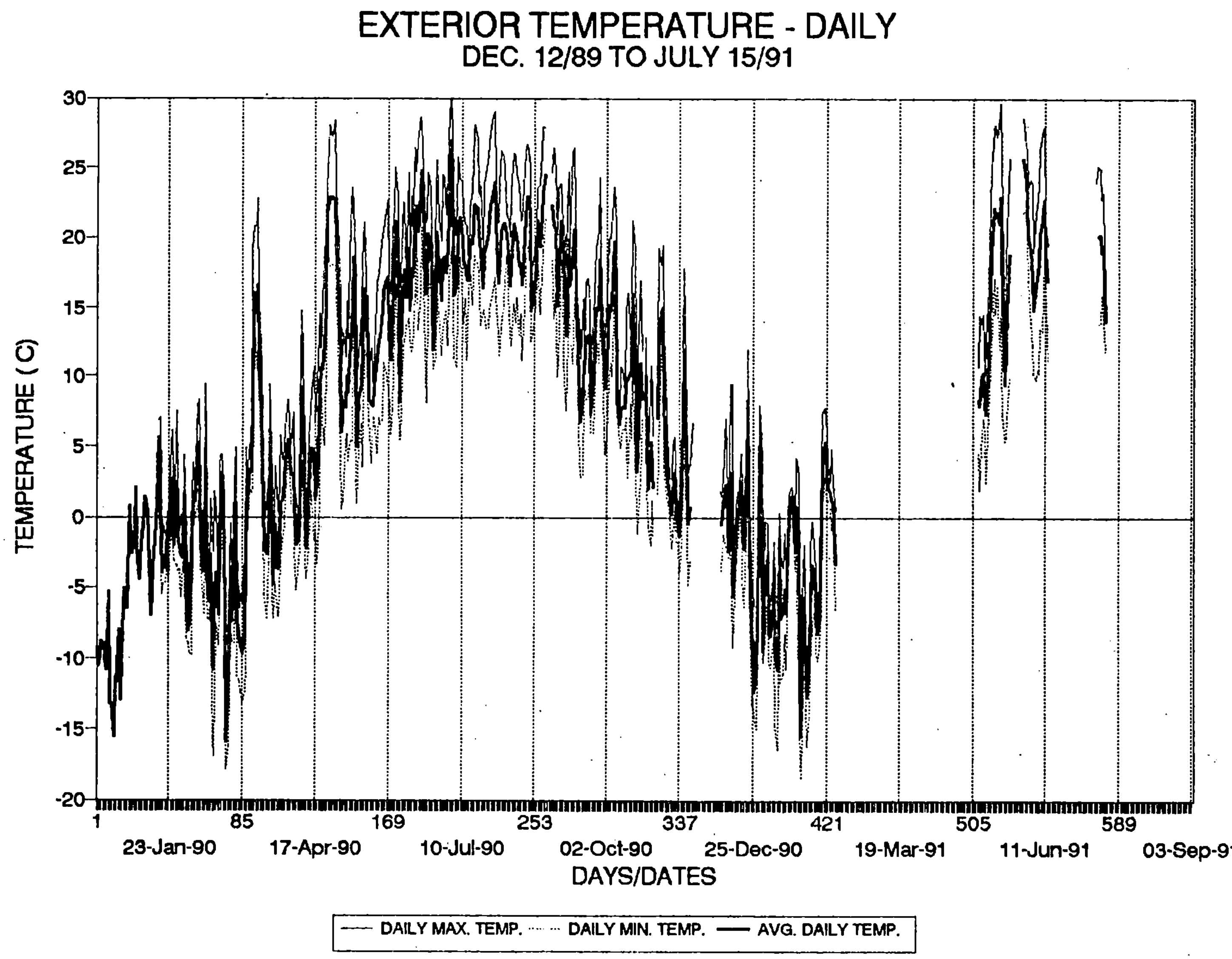
This second phase of a three-year study has demonstrated quite clearly that by the third year all the wood had dried down to base equilibrium levels of about 13% or less. Equilibrium wood moisture content values of between 10 and 13% seem to be consistent with the nature of southwestern Ontario's climate. It is worth noting that ASHRAE intends to use 12% as the reference moisture content for the documentation of wood properties. At these moisture content levels, the wood is not susceptible to microbiological growth.

As in Phase 1, the lower or bottom plate always seemed to be wetter and colder than the other framing lumber. This was not entirely unanticipated but, in this project, we believe that the lower plate may have been exposed in a non-representative manner. For this reason, we recommend that emphasis be placed on the results from the vertical studs and top plate. Nevertheless, it is significant that by the third year the bottom plate had generally dried down to nearly the same levels as the other framing elements. The bottom plate also seemed more susceptible to variations in the weather. We recommend that the bottom plate be better detailed in future research to avoid the foregoing reservations.

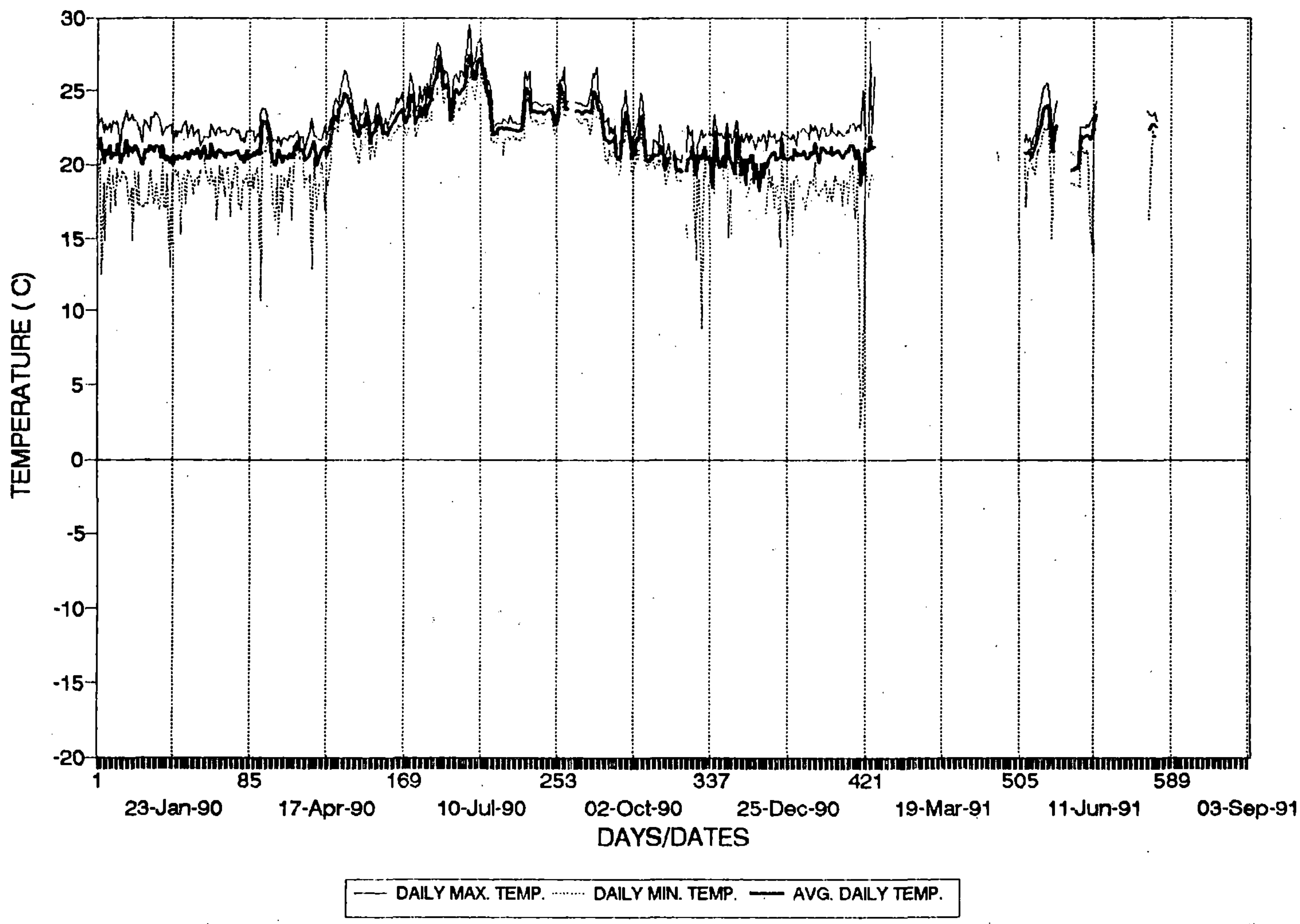
In summary, over the course of both phases of this project, it has been demonstrated that the nine representative wall systems all performed satisfactorily. They all dried down to acceptable levels relatively quickly (well below 19%). By the third year all the framing lumber, and probably the wall system as a whole, had dried down to levels that were essentially constant and relatively dry (13% or less). It seems fair to conclude that this has been a useful, practical and instructive R and D project.

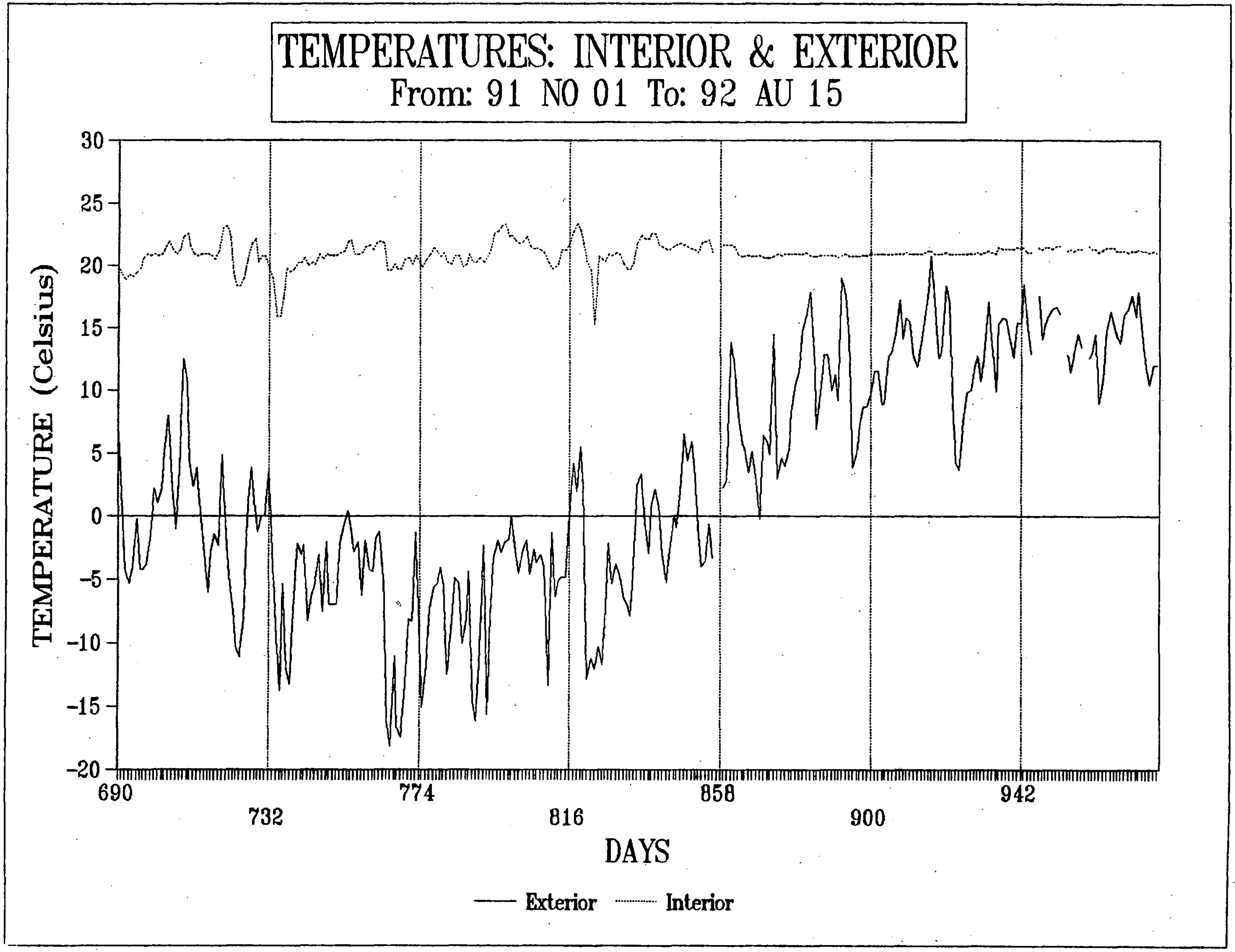
APPENDIX A: INTERNAL AND EXTERNAL ENVIRONMENT AND DATES/DAY NUMBERS

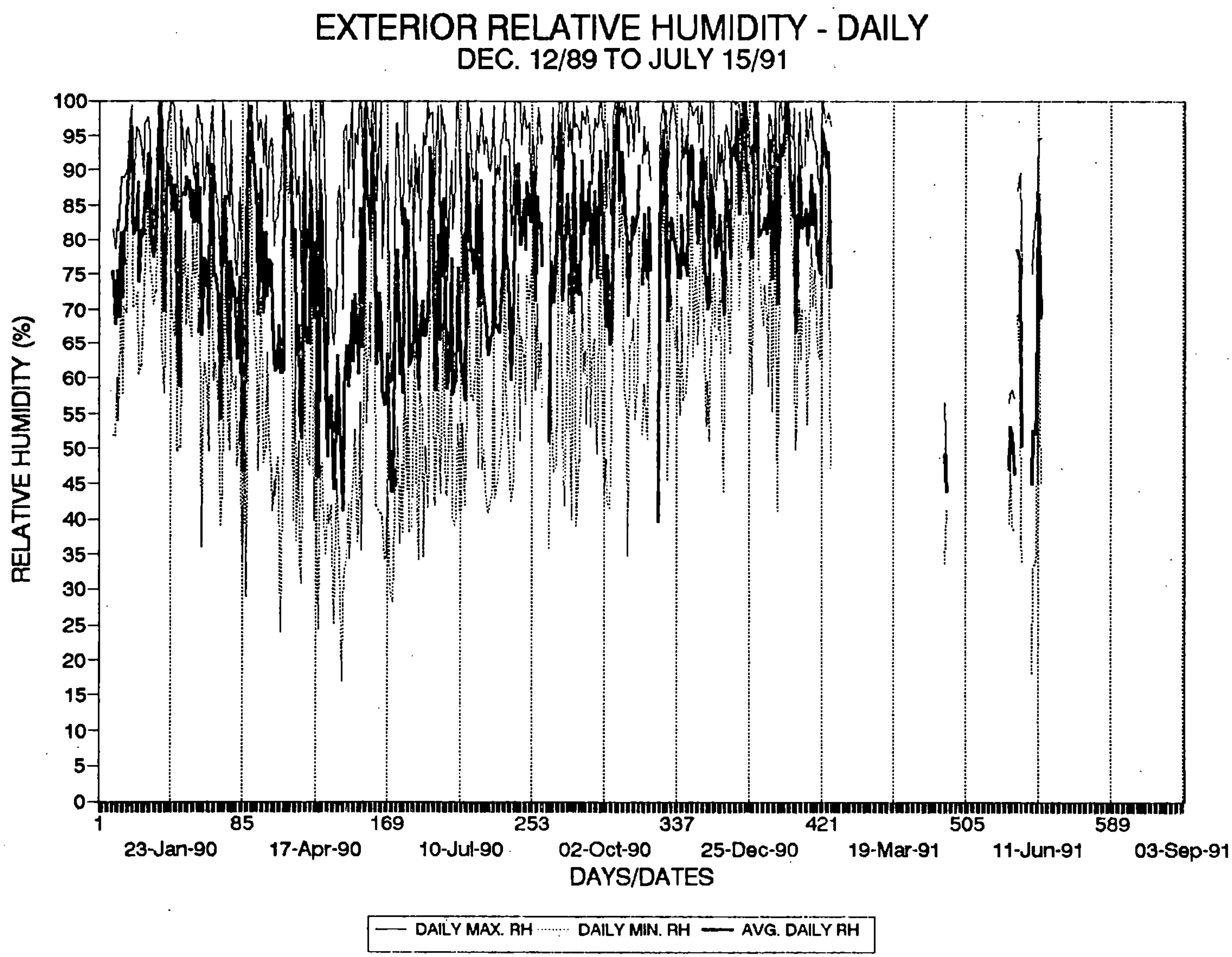
Phase I	Day	Date
	1	12-Dec-89
	43	23-Jan-90
	85	06-Mar-90
	127	17-Apr-90
	169	29-May-90
	211	10-Jul-90
	253	21-Aug-90
	295	02-Oct-90
	337	13-Nov-90
	379	25-Dec-90
	421	05-Feb-91
	463	19-Mar-91
	505	30-Apr-91
	547	11-Jun-91
	589	23-Jul-91
	631	03-Sep-91
	673	15-Oct-91
Phase II	Day	Date
	690	01-Nov-91
	732	13-Dec-91
	774	24-Jan-92
	816	06-Mar-92
	858	17-Apr-92
	900	29-May-92
	942	10-Jul-92
	984	21-Aug-92


EXTERIOR TEMPERATURE - DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATES
DAILY MAX. TEMP.
DAILY MIN. TEMP.
AVG. DAILY TEMP.

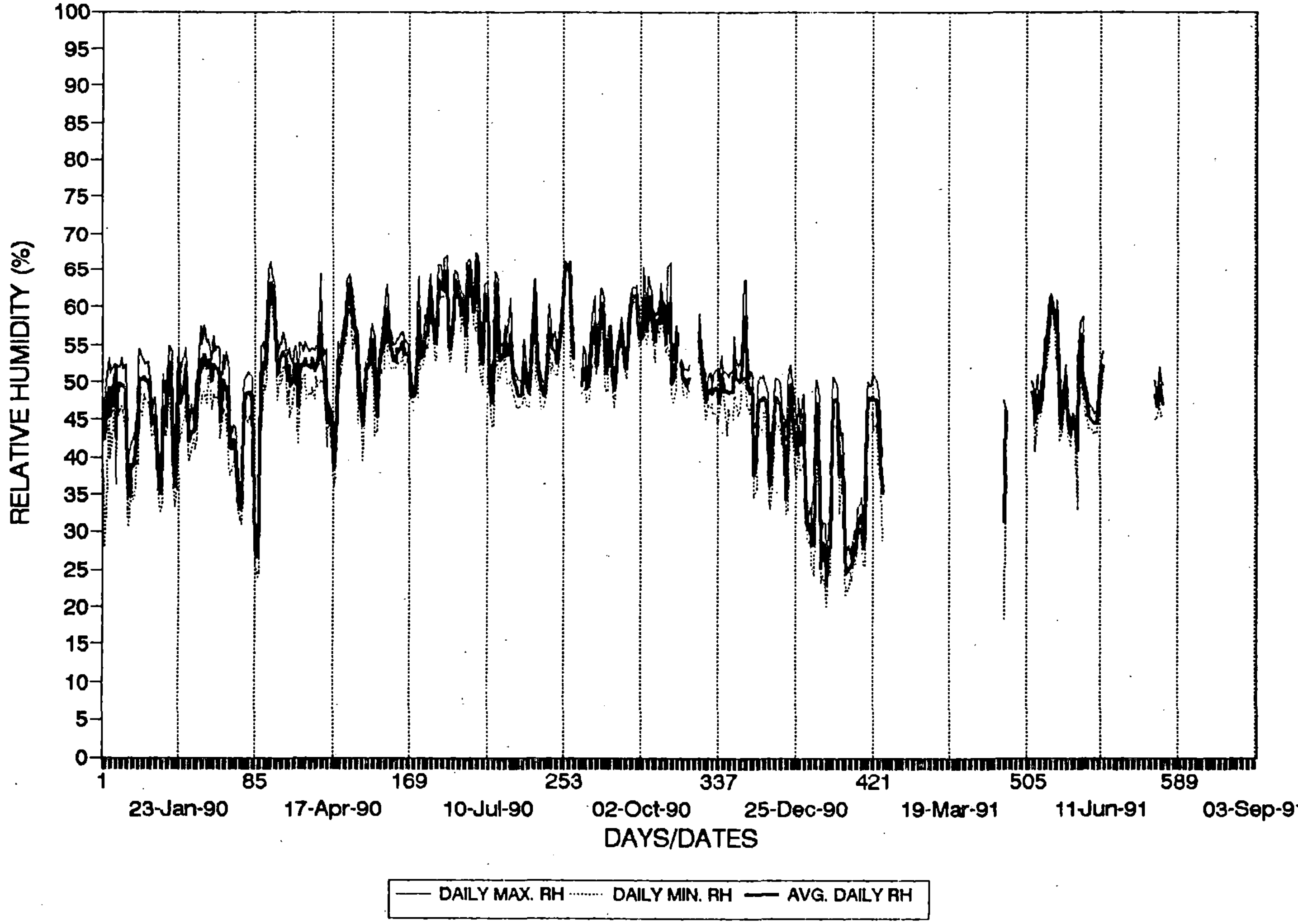
INTERIOR TEMPERATURE - DAILY
DEC. 12/89 TO JULY 15/91

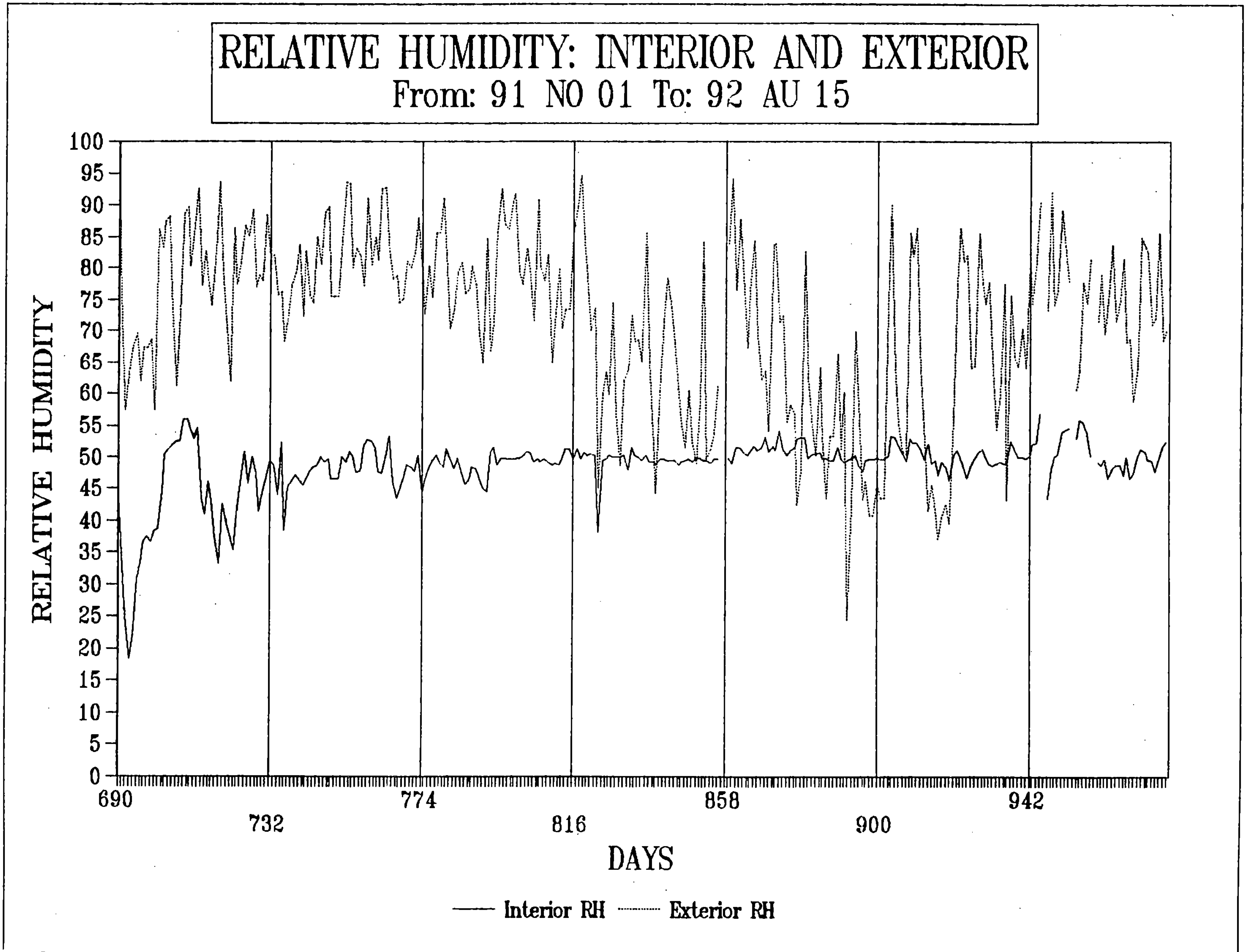



TEMPERATURES: INTERIOR & EXTERIOR
From: 91 NO 01 To: 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Exterior
Interior


EXTERIOR RELATIVE HUMIDITY - DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATES
DAILY MAX. RH
DAILY MIN. RH
AVG. DAILY RH

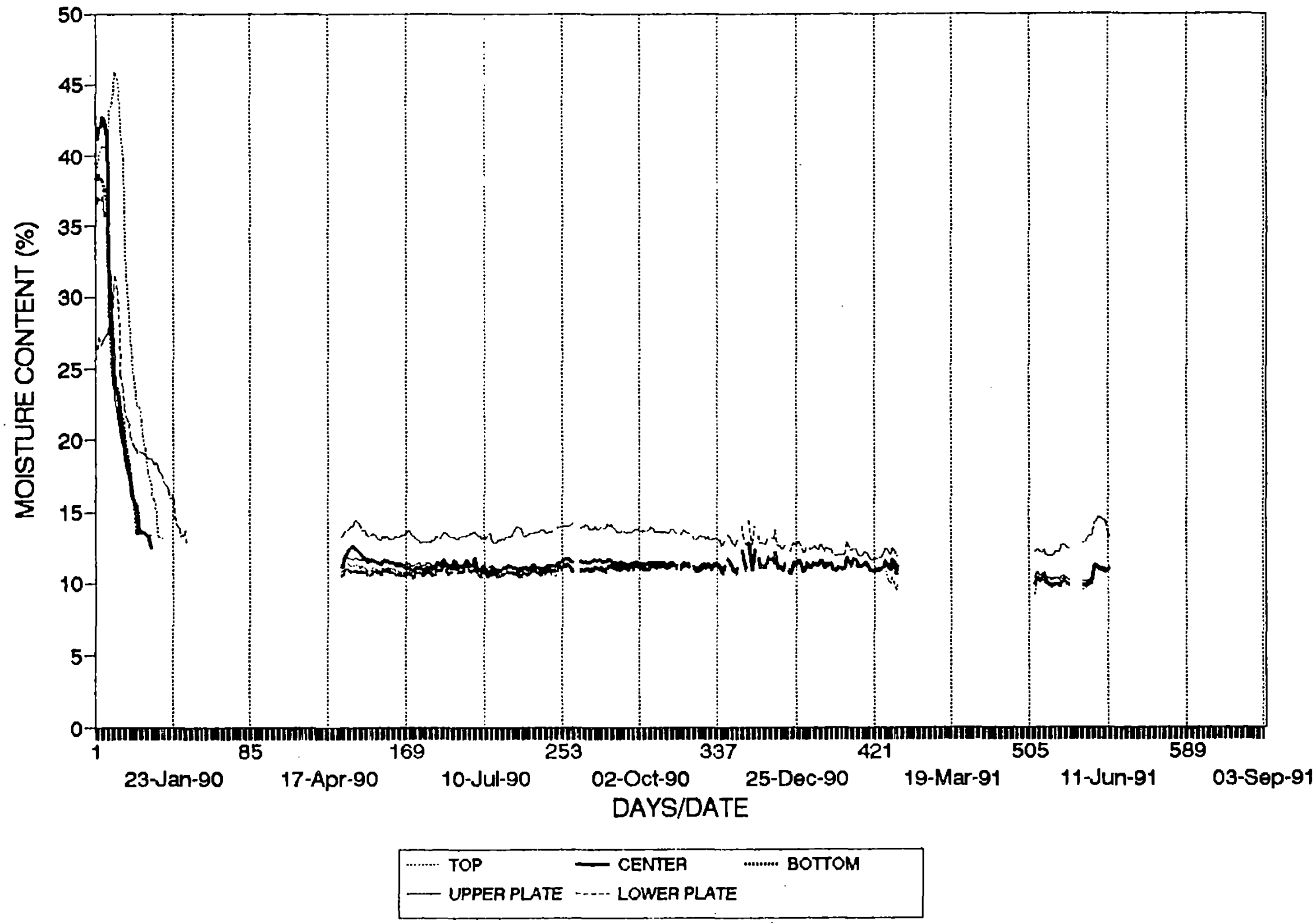
INTERIOR RELATIVE HUMIDITY - DAILY
DEC. 12/89 TO JULY 15/91

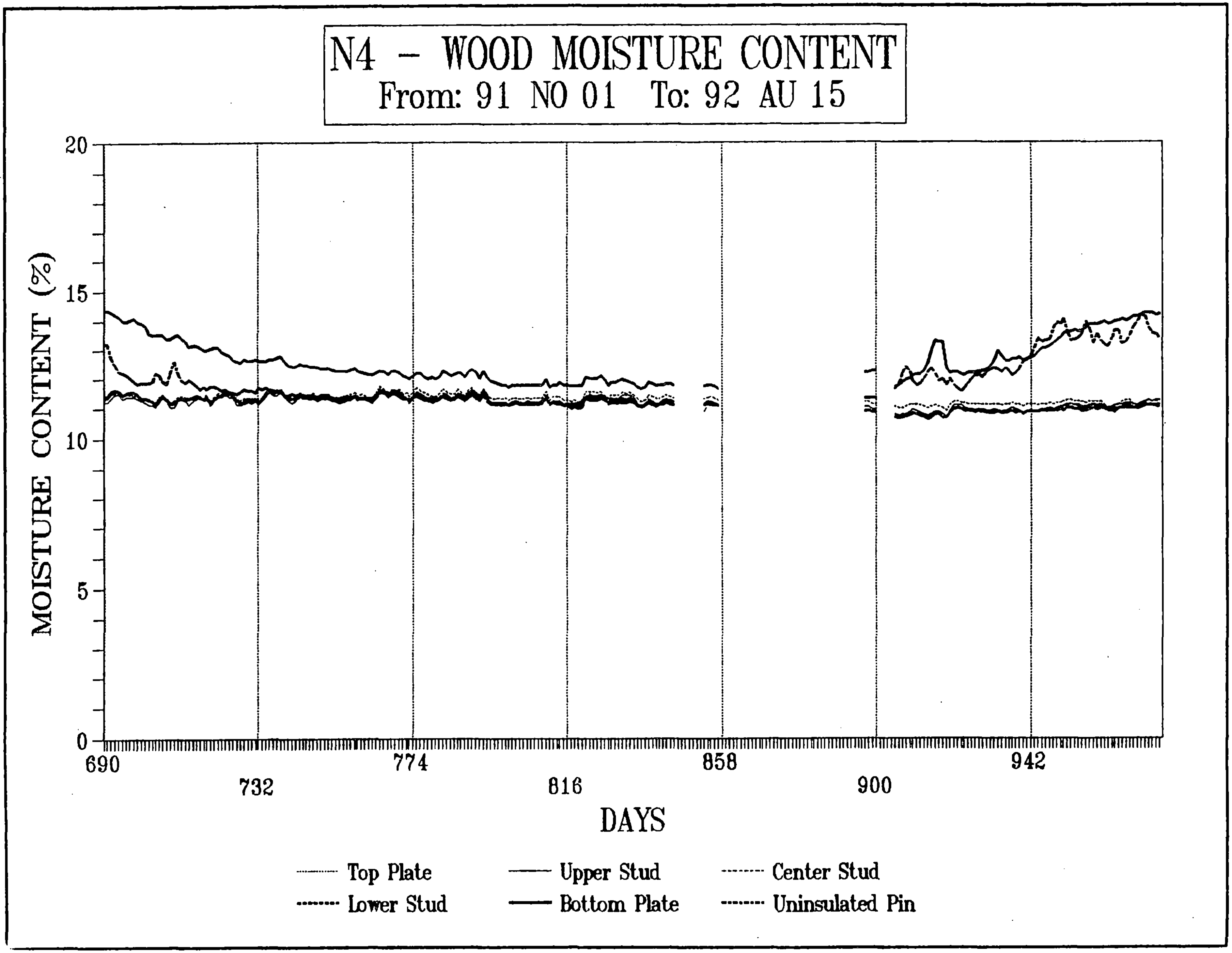


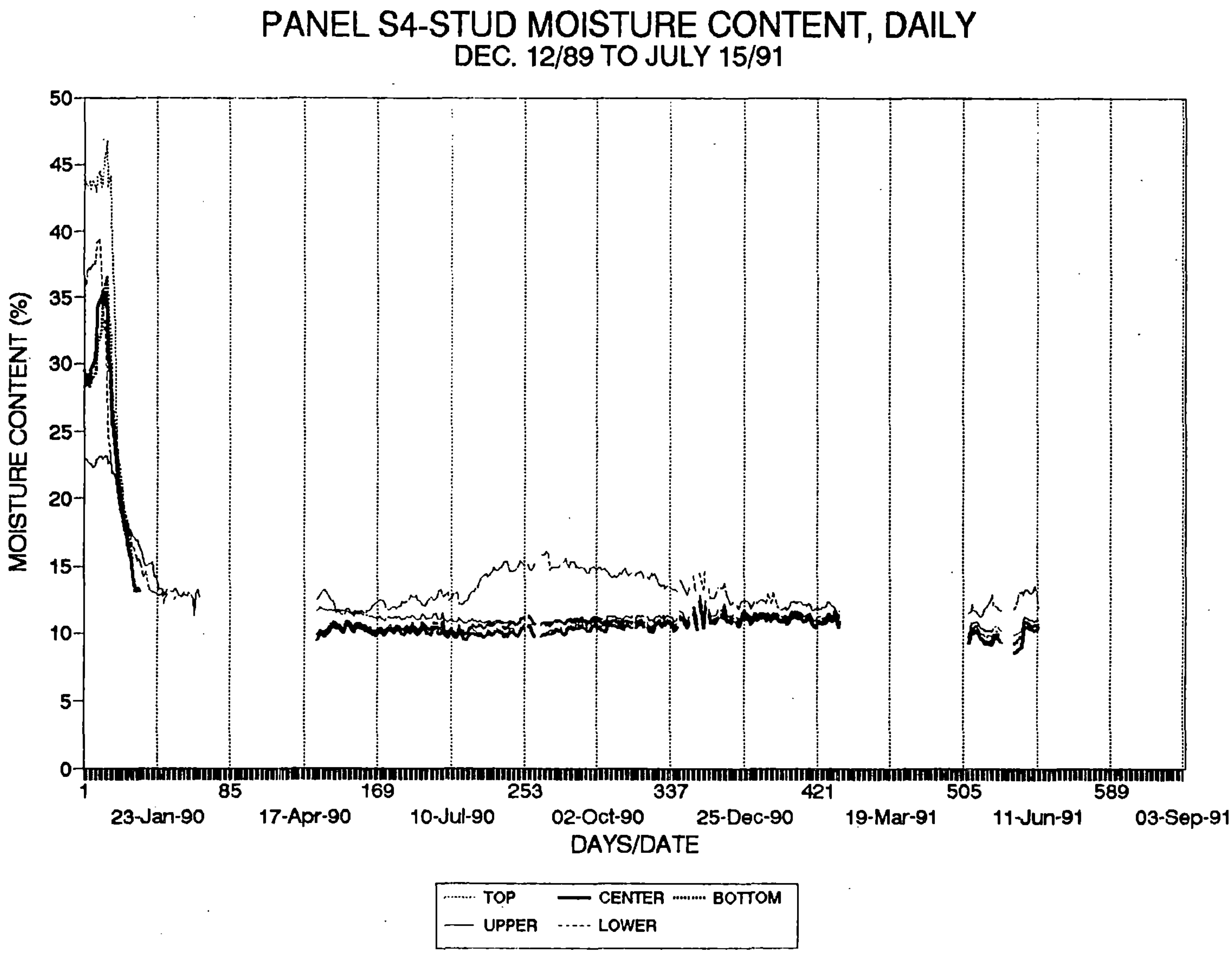

RELATIVE HUMIDITY: INTERIOR AND EXTERIOR
From: 91 NO 01 To: 92 AU 15
RELATIVE HUMIDITY
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Interior RH
Exterior RH

APPENDIX B: PANELS N4,S4 AND E4,W4

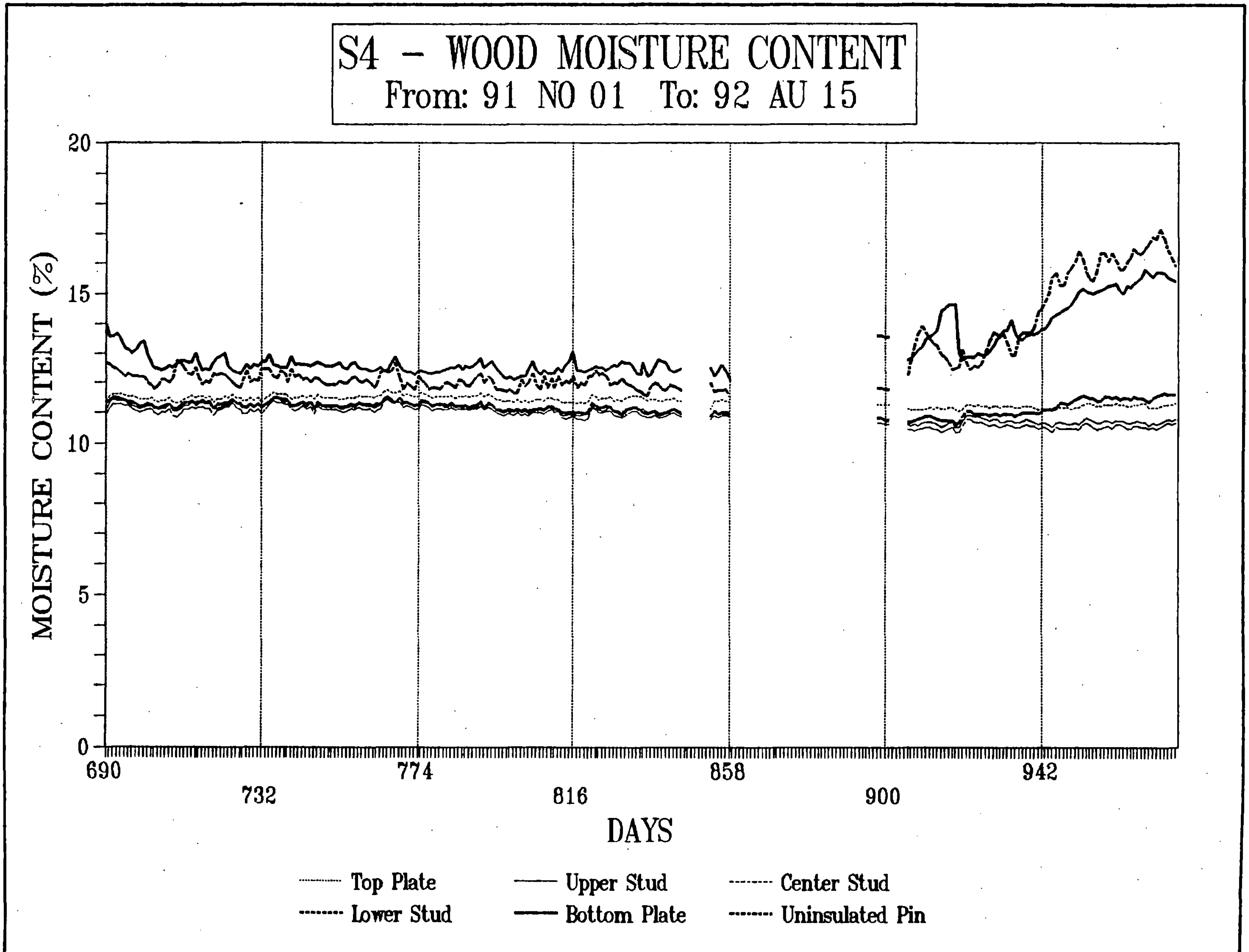
PANEL N4-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91



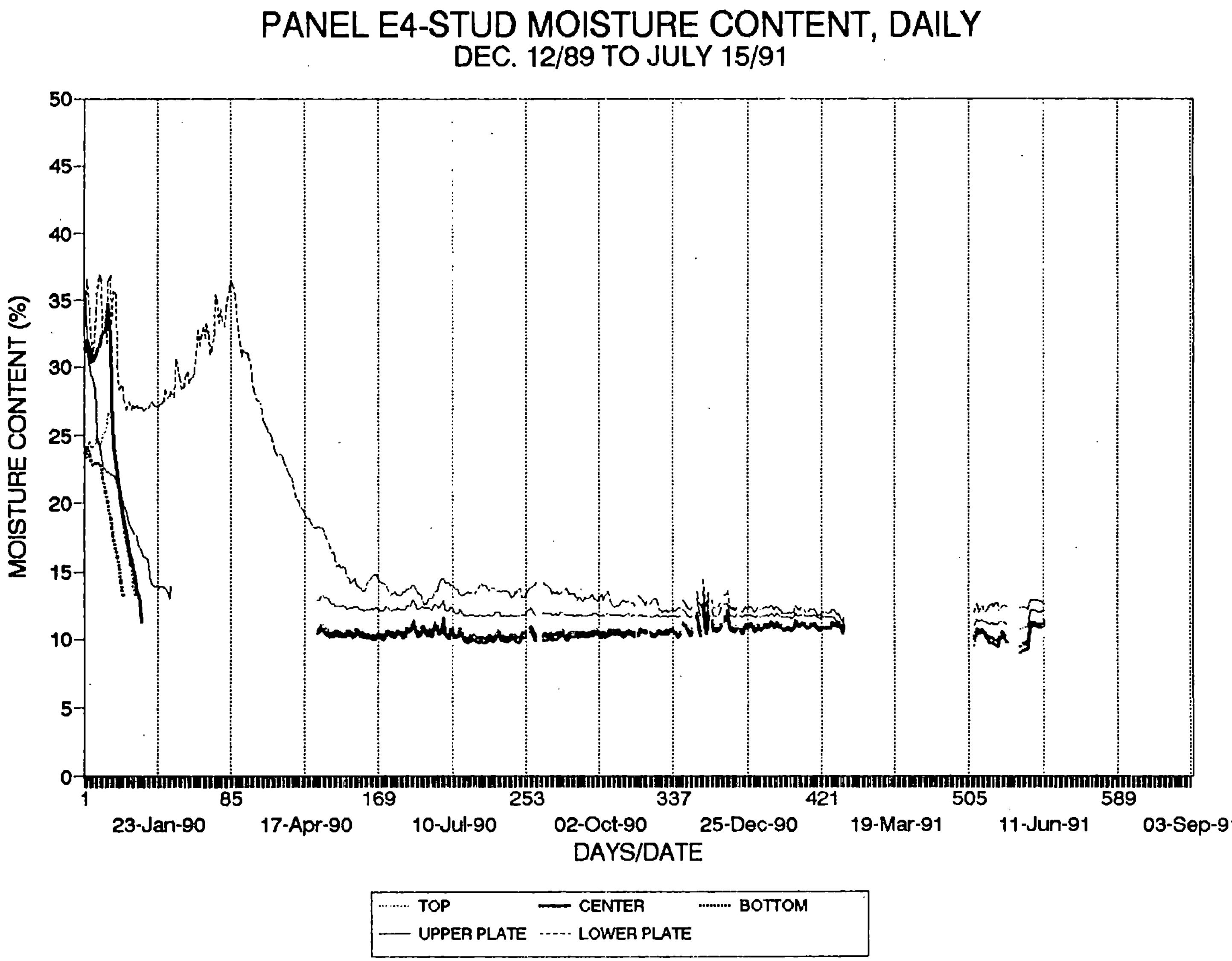

N4 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin



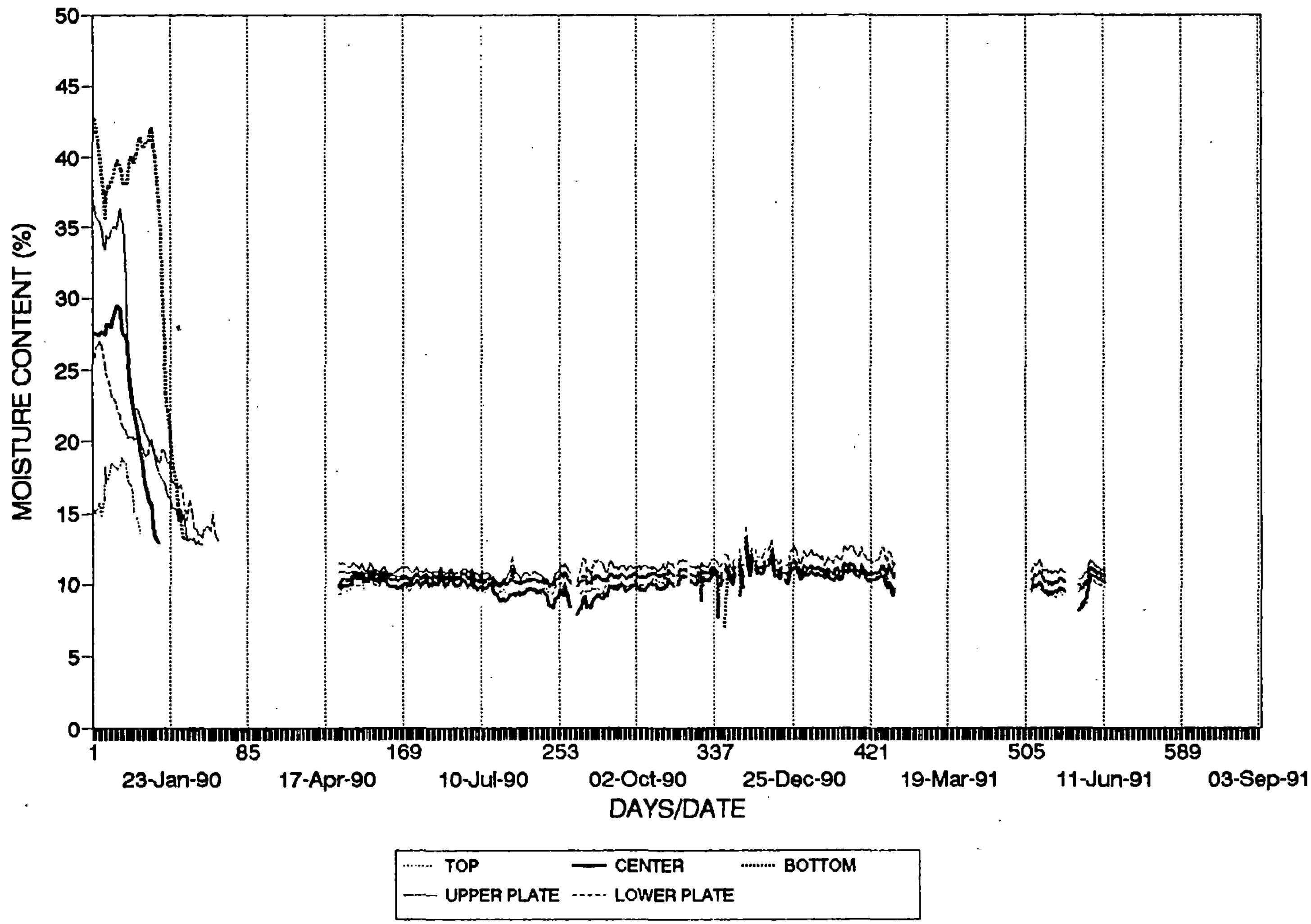
PANEL S4-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER
LOWER

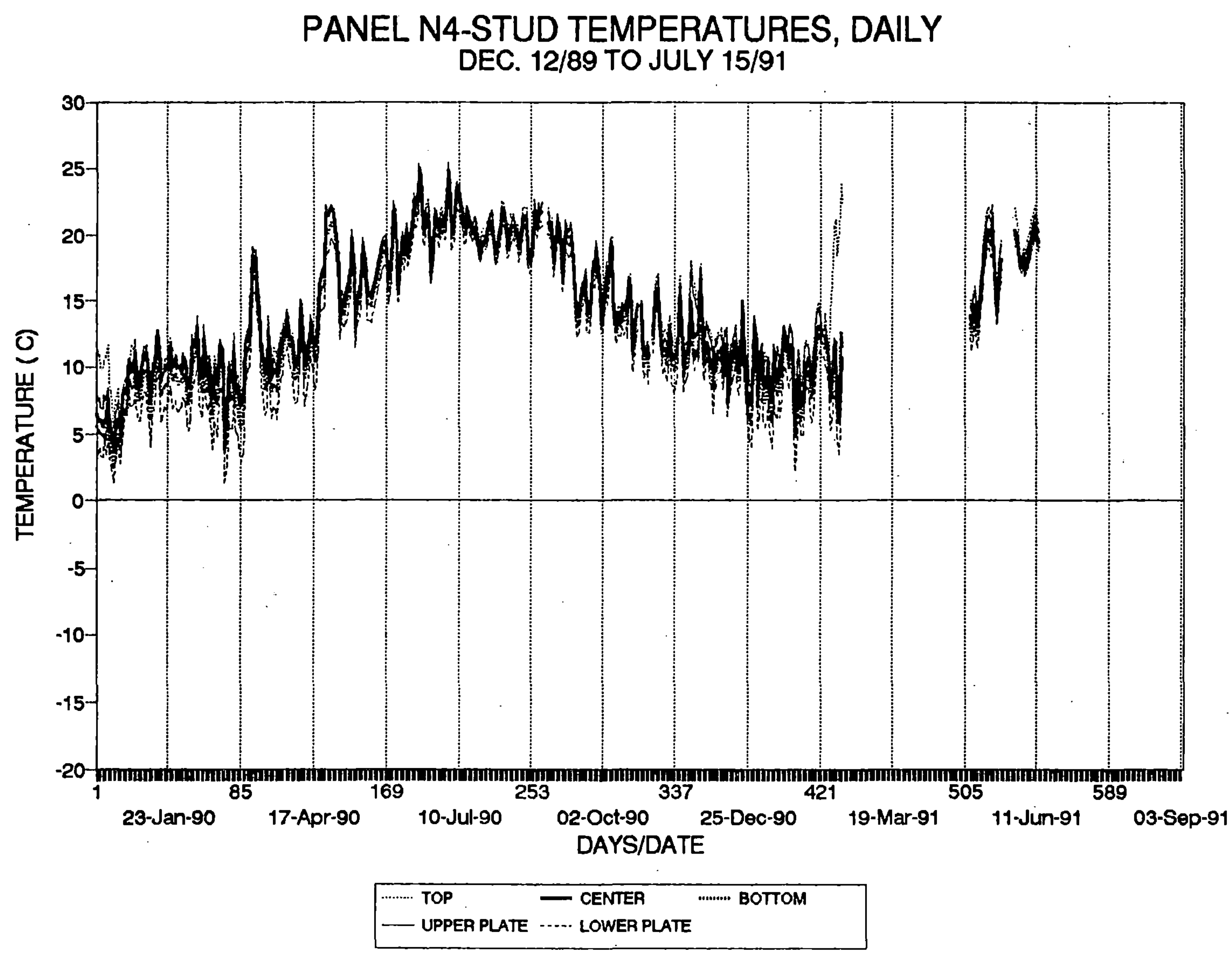


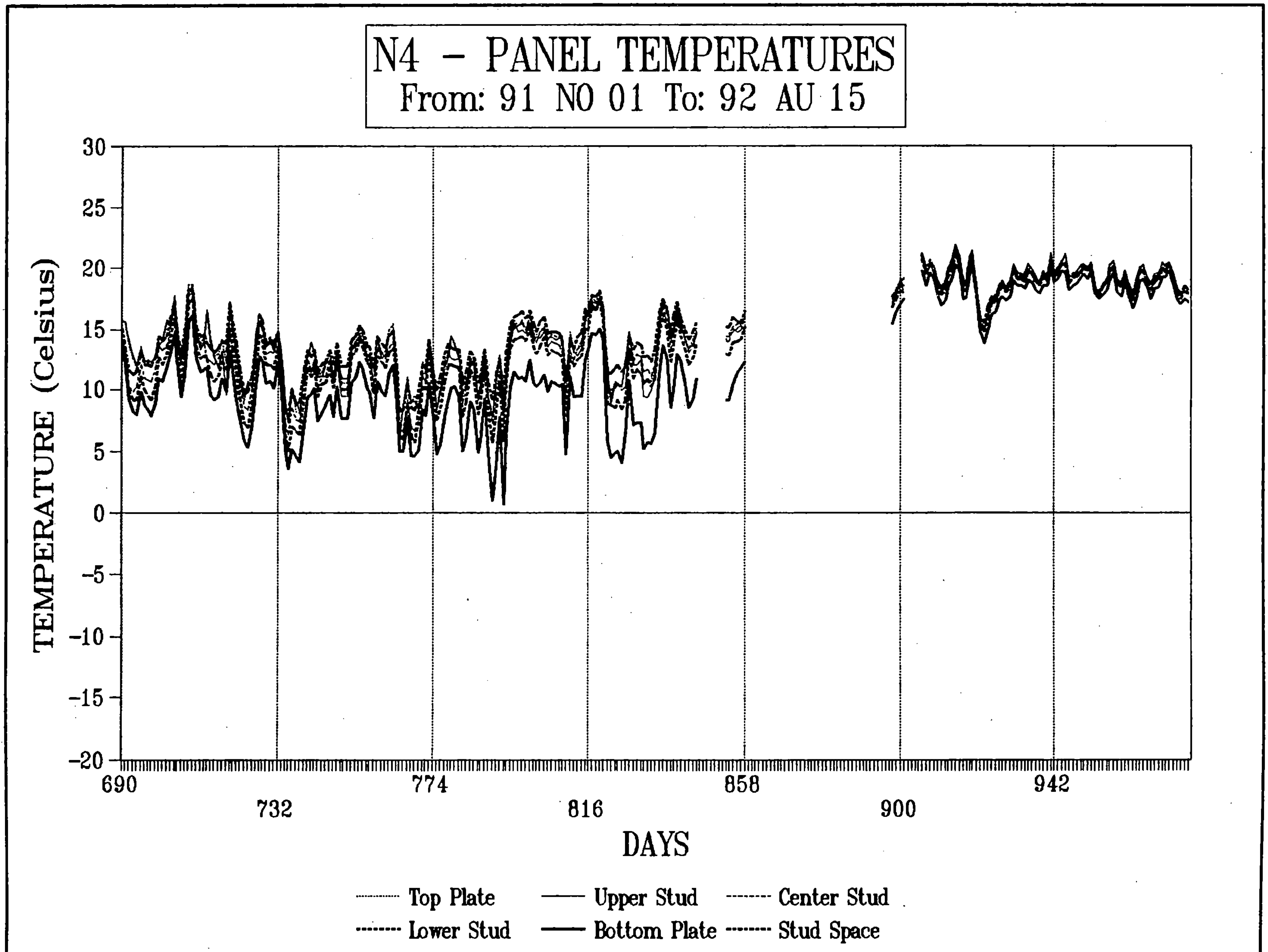
S4 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin


PANEL E4-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
0
5
10
15
20
25
30
35
40
45
50
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

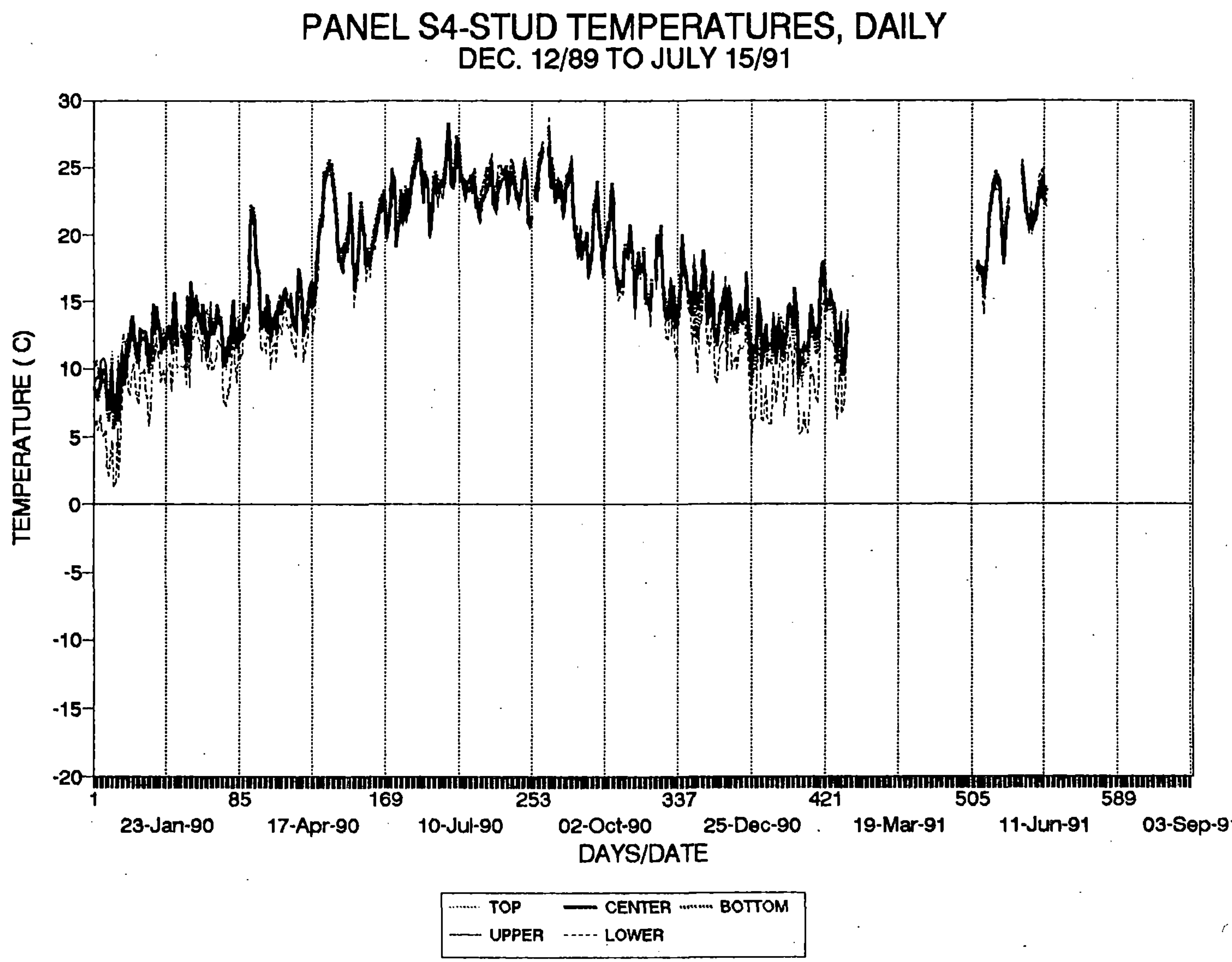
PANEL W4-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91

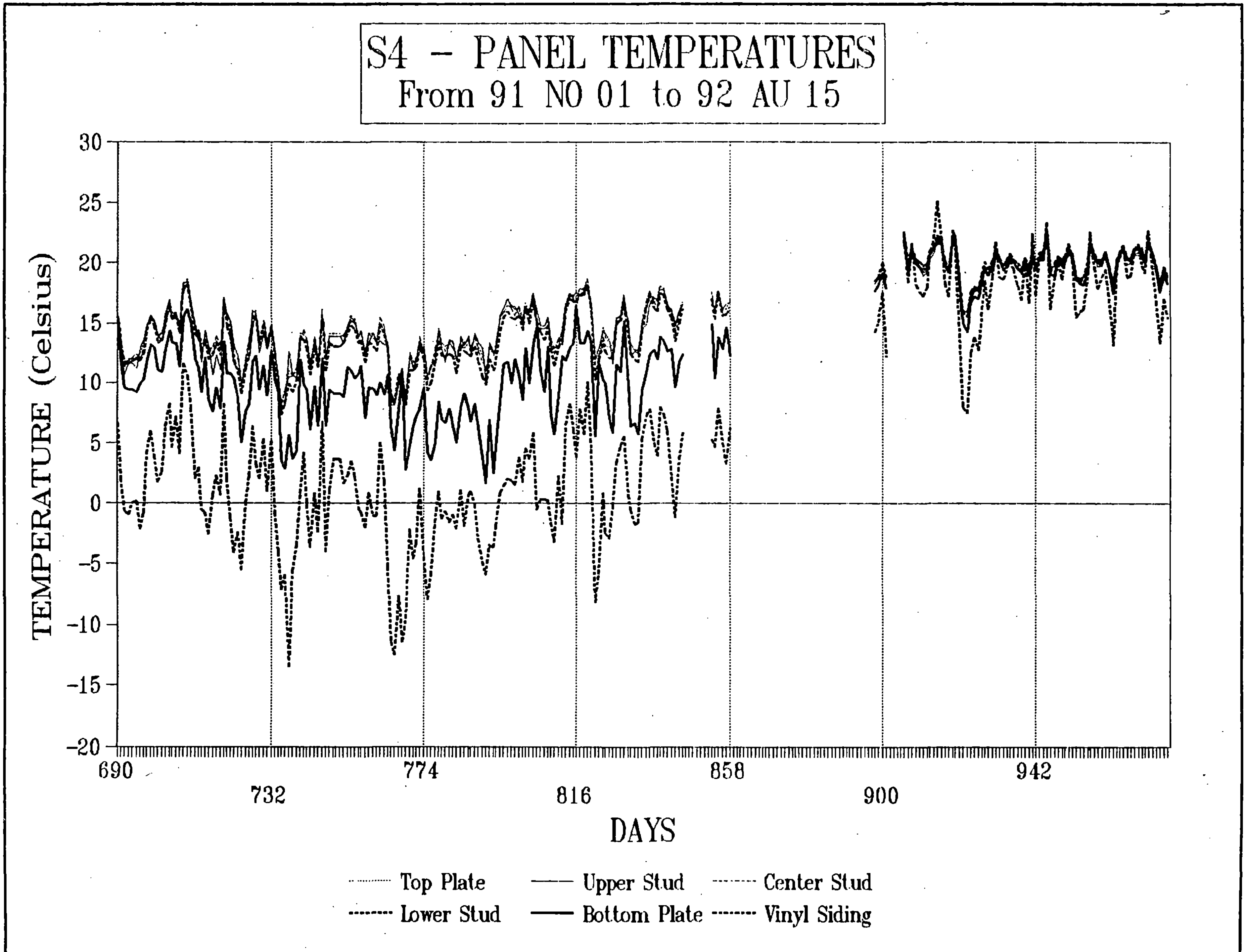



PANEL N4-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

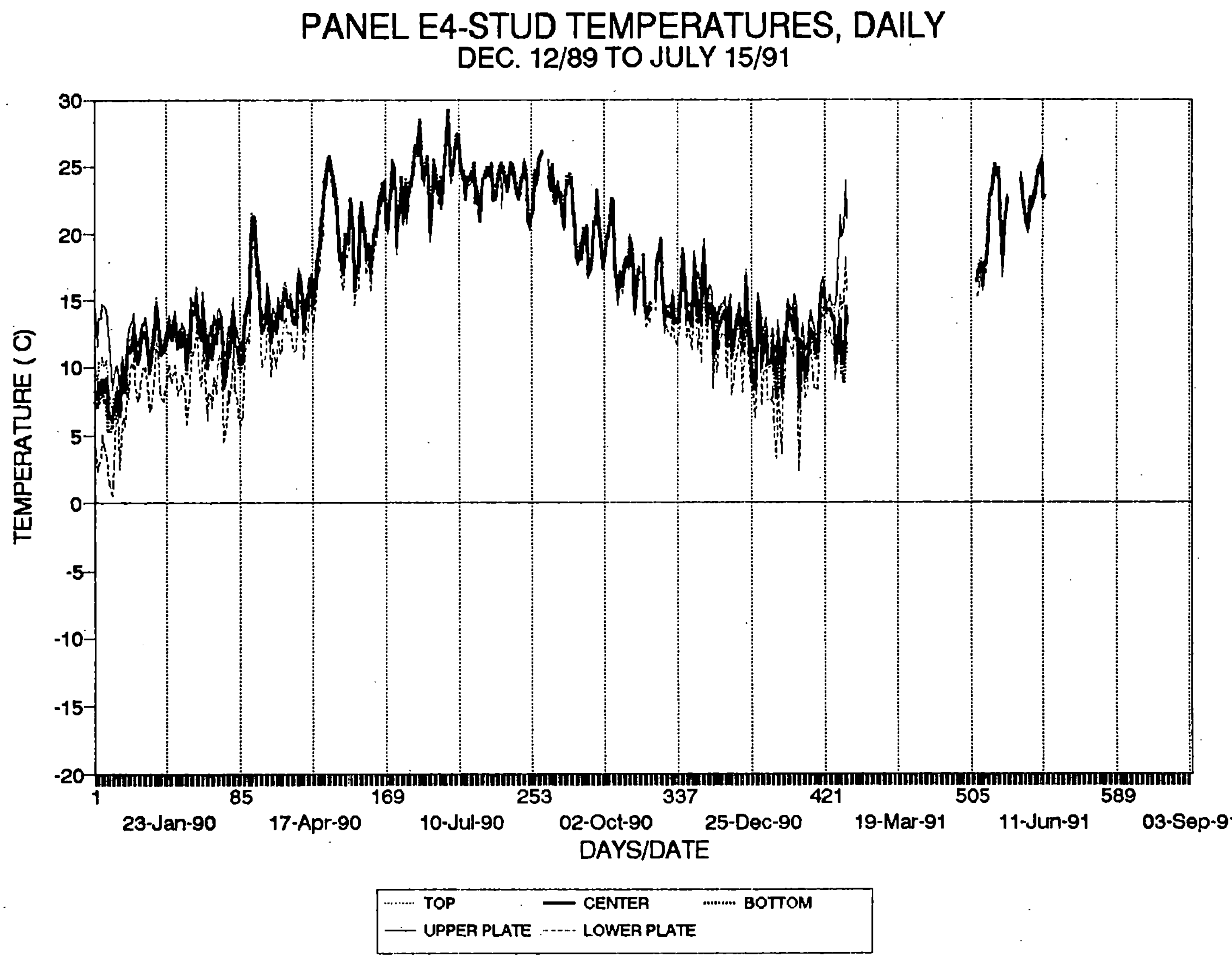


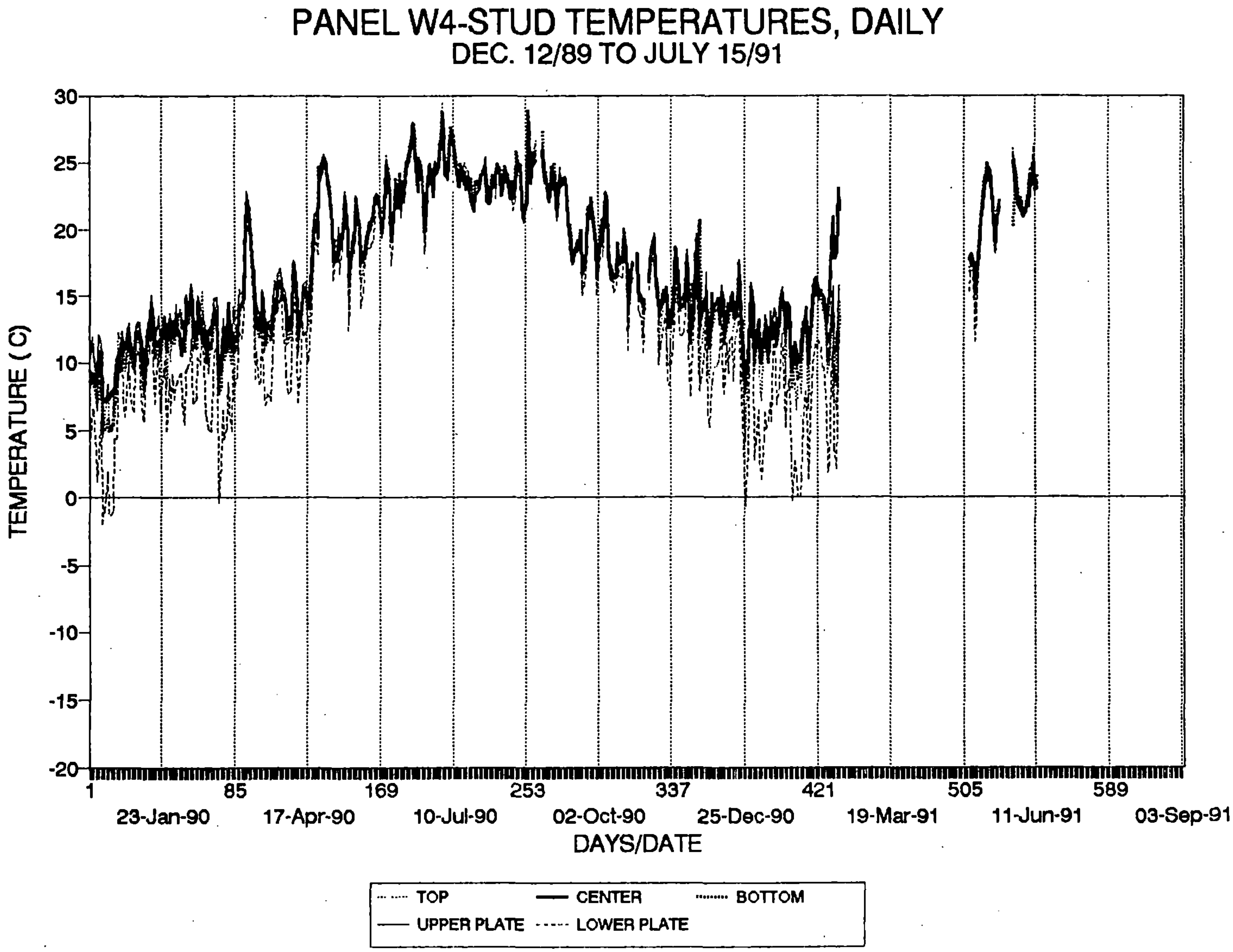
N4 - PANEL TEMPERATURES
From: 91 NO 01 To: 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Stud Space


PANEL S4-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER
LOWER



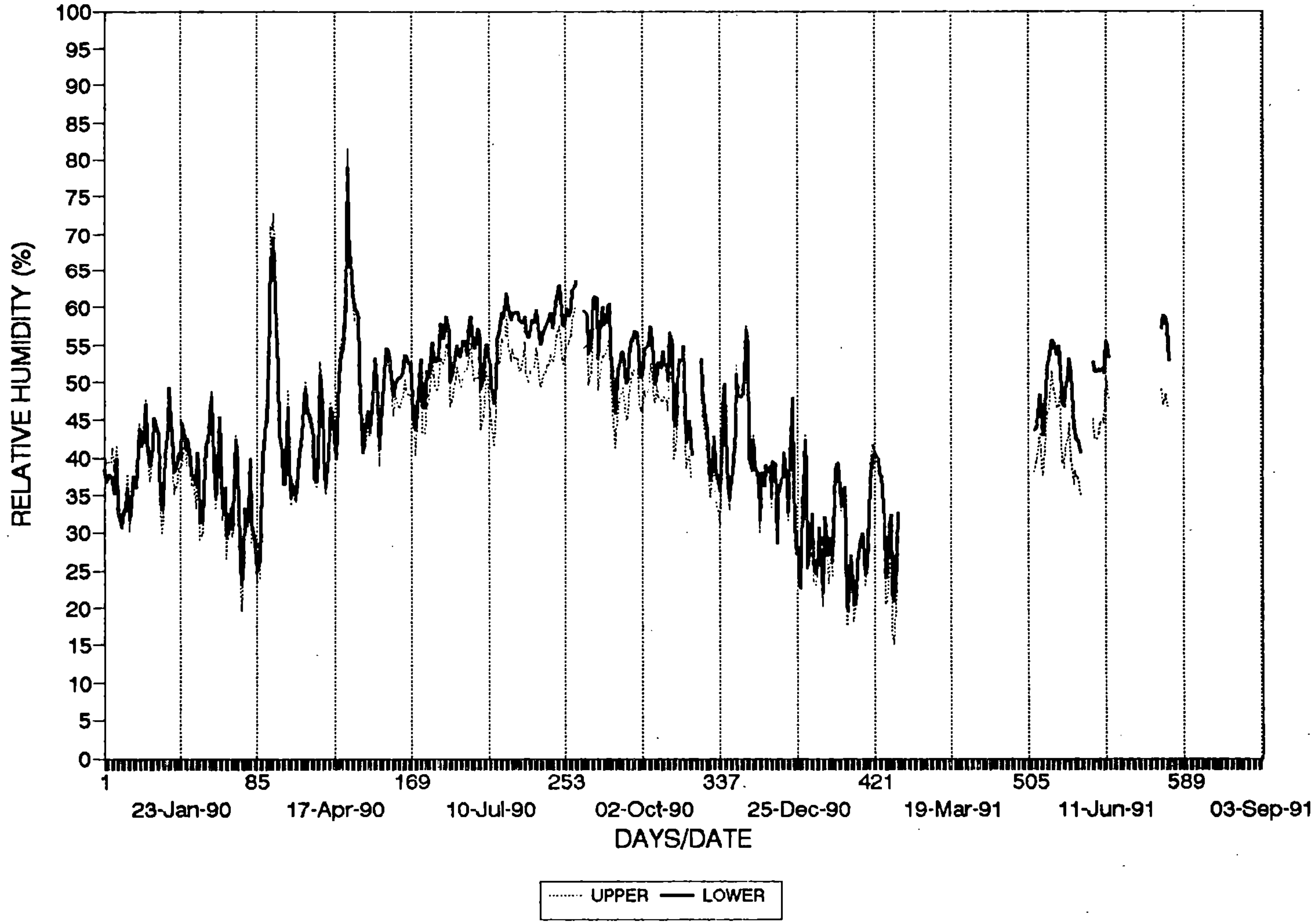
S4 - PANEL TEMPERATURES
From 91 NO 01 to 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Vinyl Siding

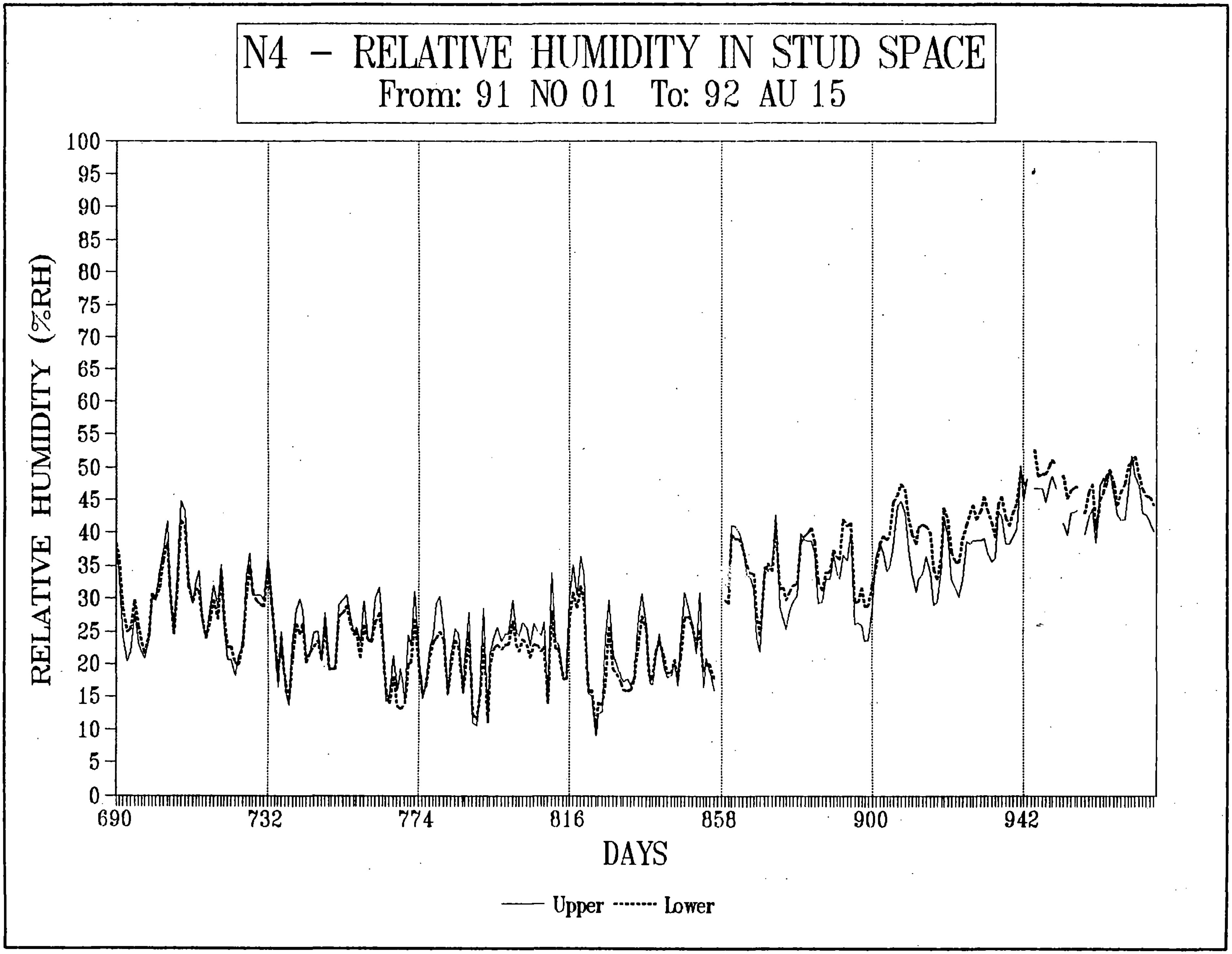

PANEL E4-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

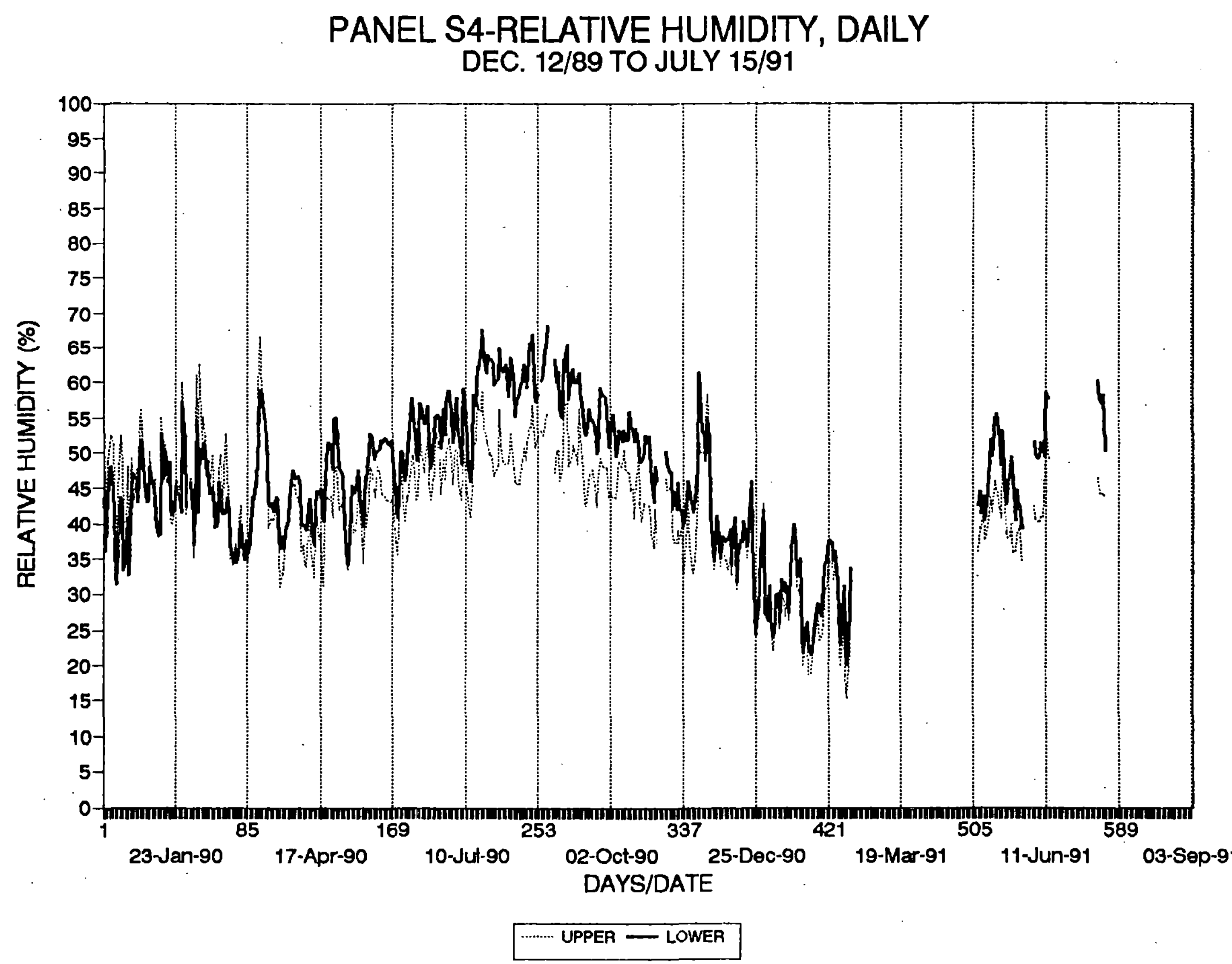


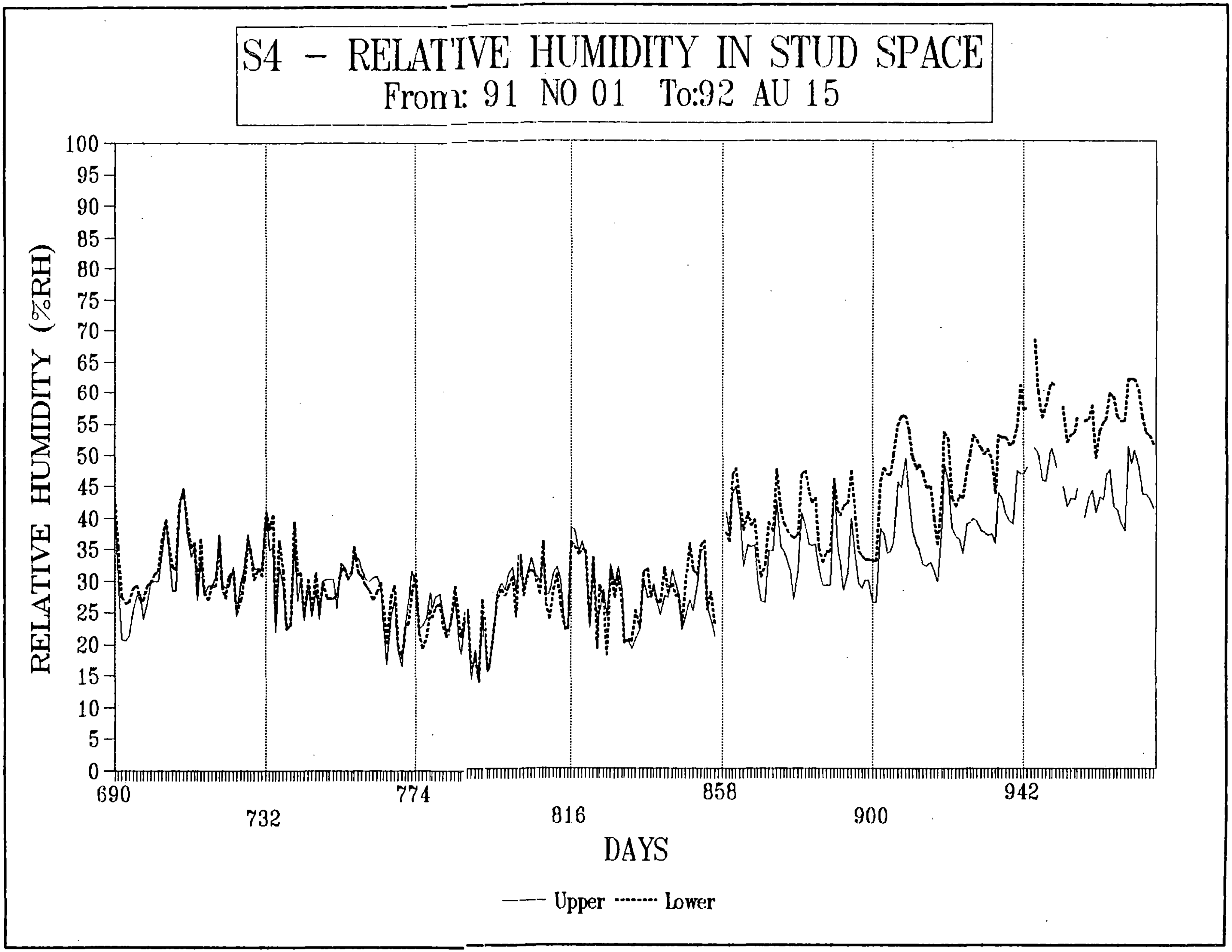
PANEL W4-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

PANEL N4-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91

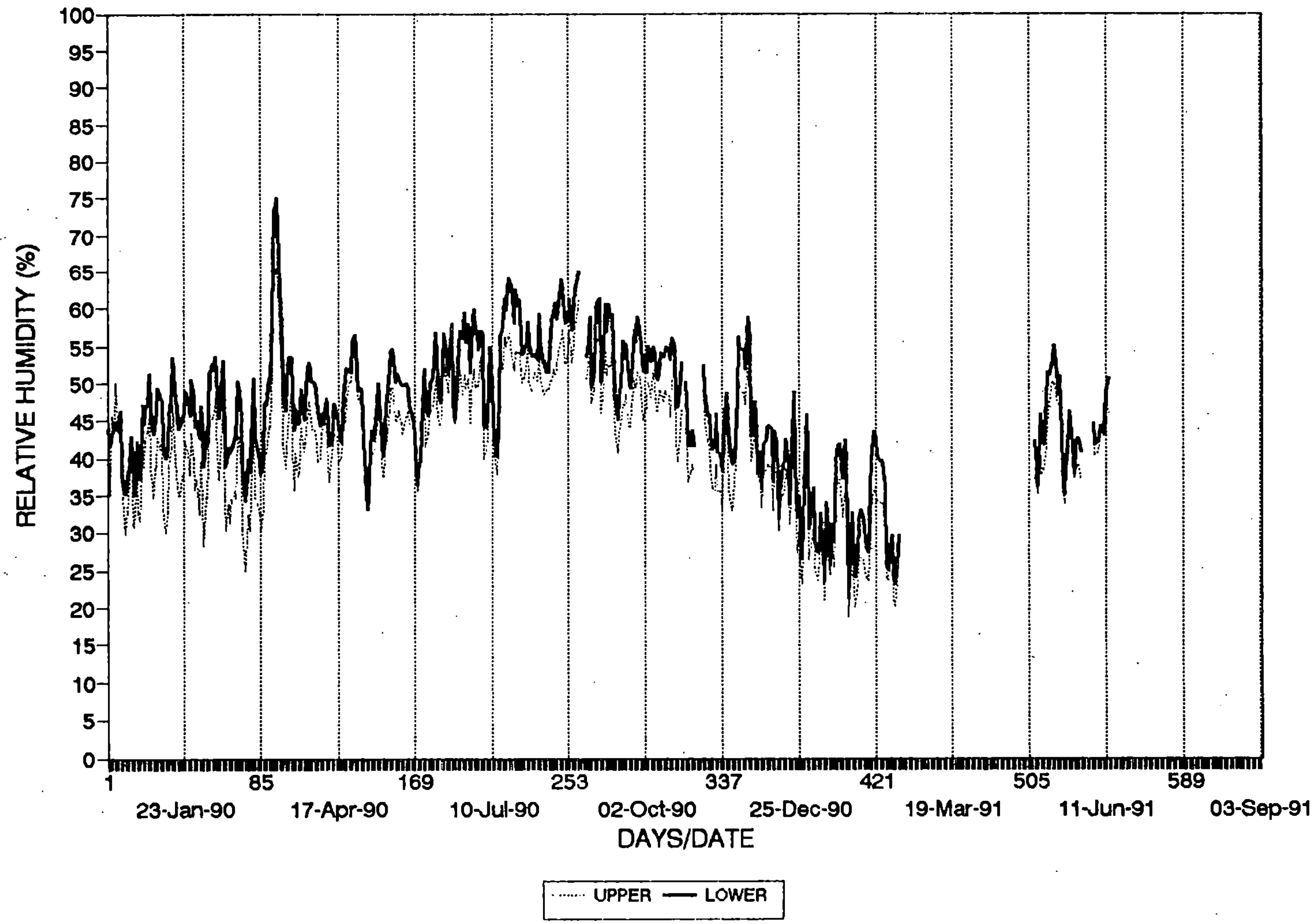



N4 - RELATIVE HUMIDITY IN STUD SPACE
From: 91 NO 01 To: 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower

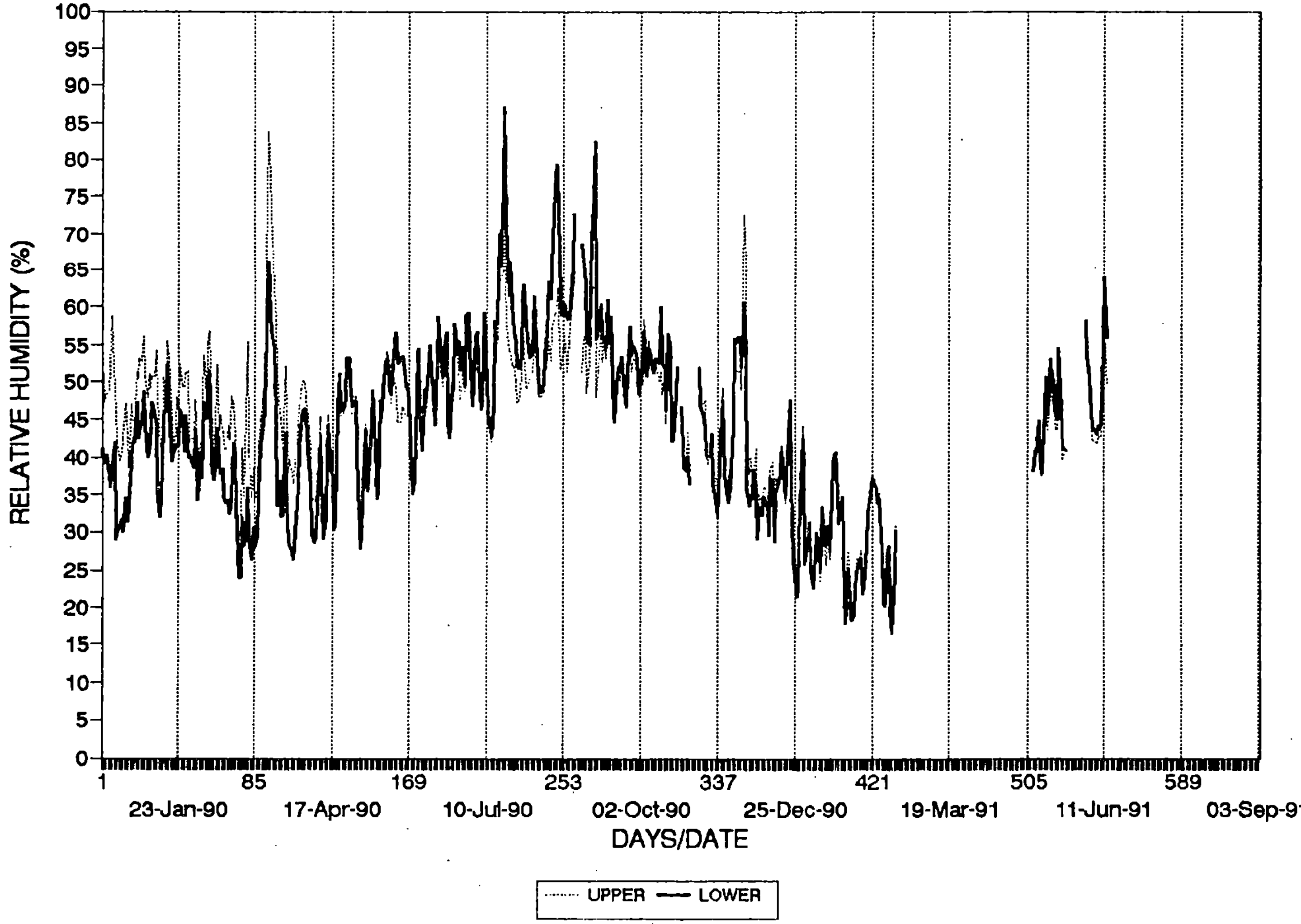

PANEL S4-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER


S4 - RELATIVE HUMIDITY IN STUD SPACE
From: 91 NO 01 To:92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower

PANEL E4-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91

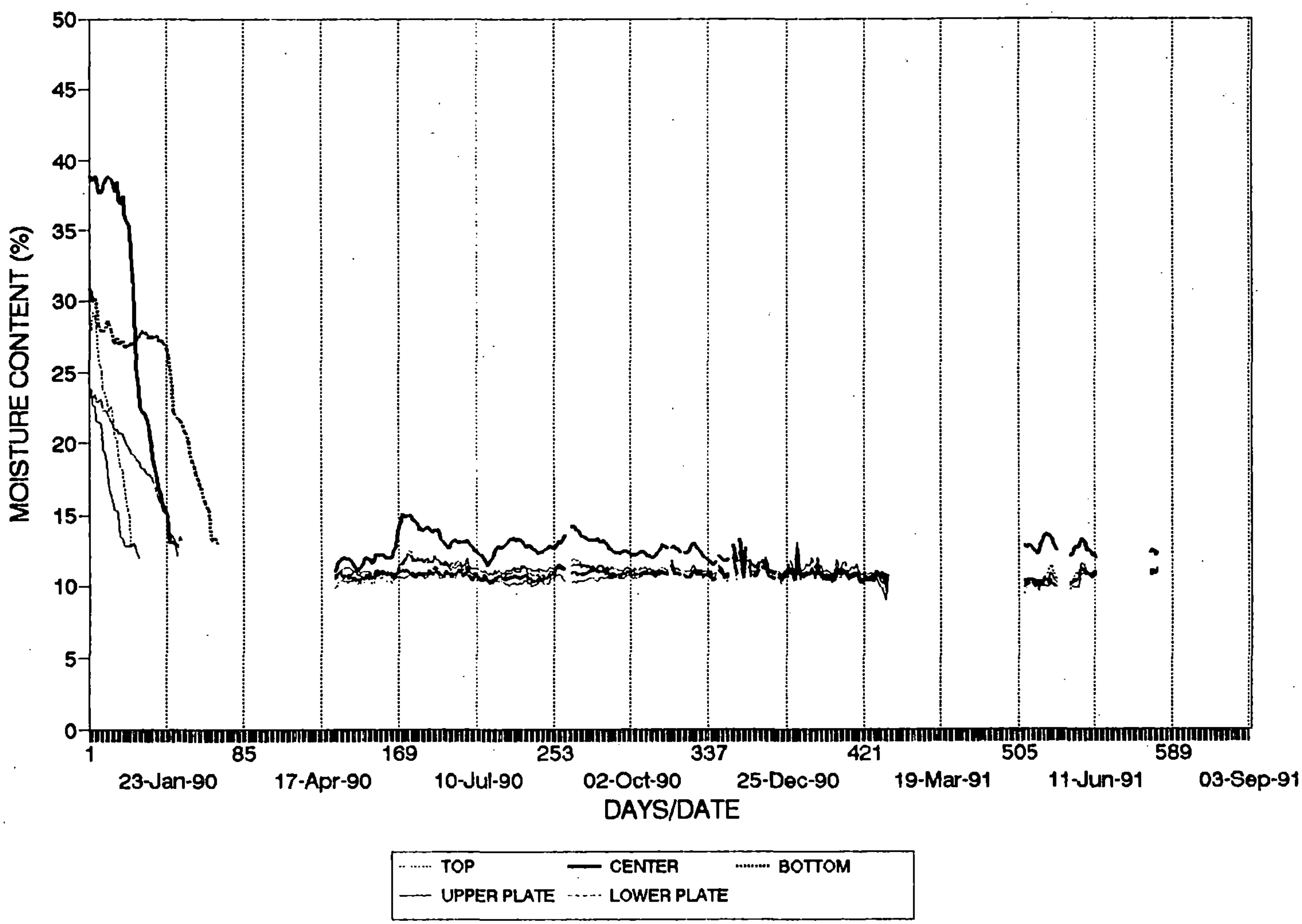


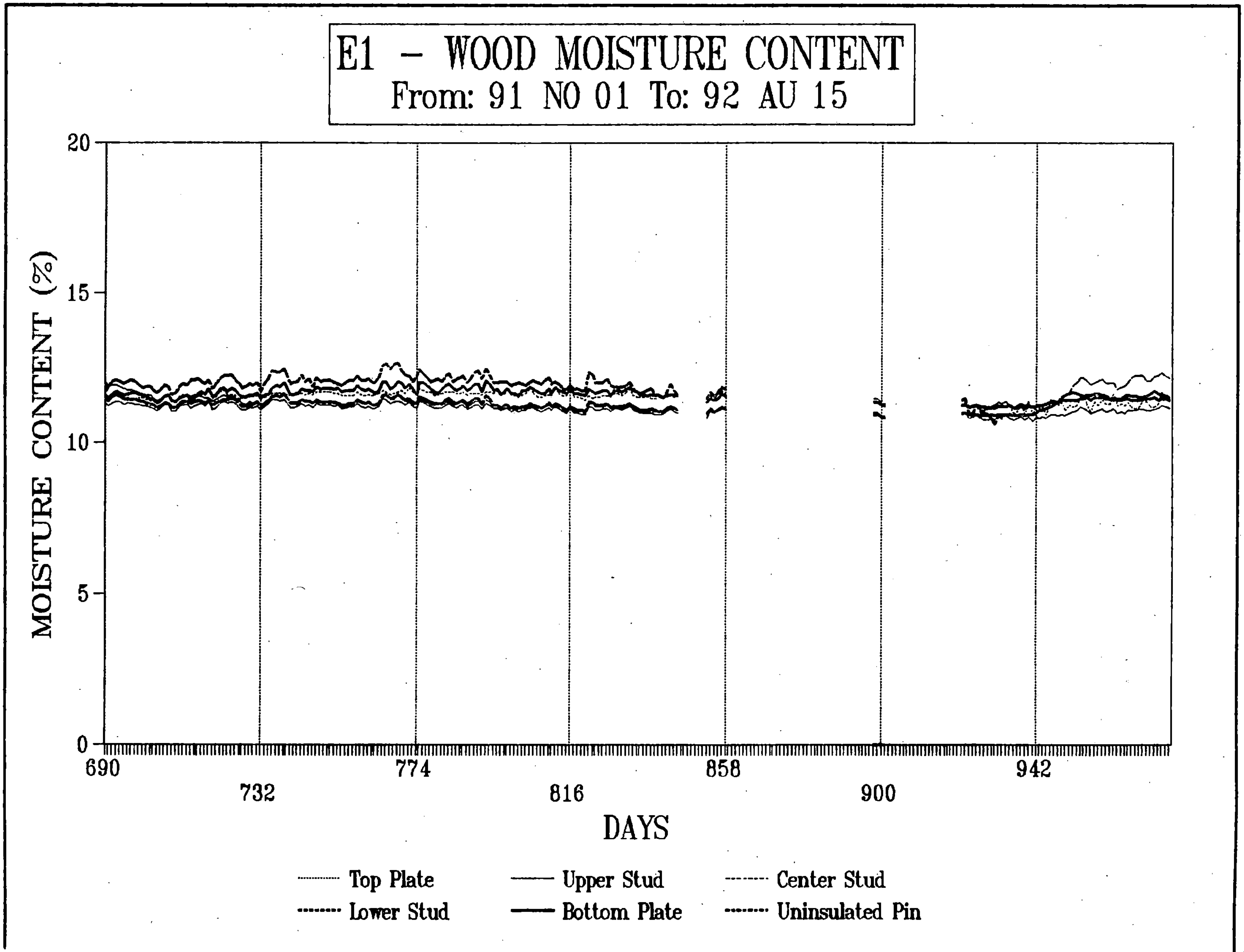
PANEL W4-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91



APPENDIX C: PANELS E1,W1

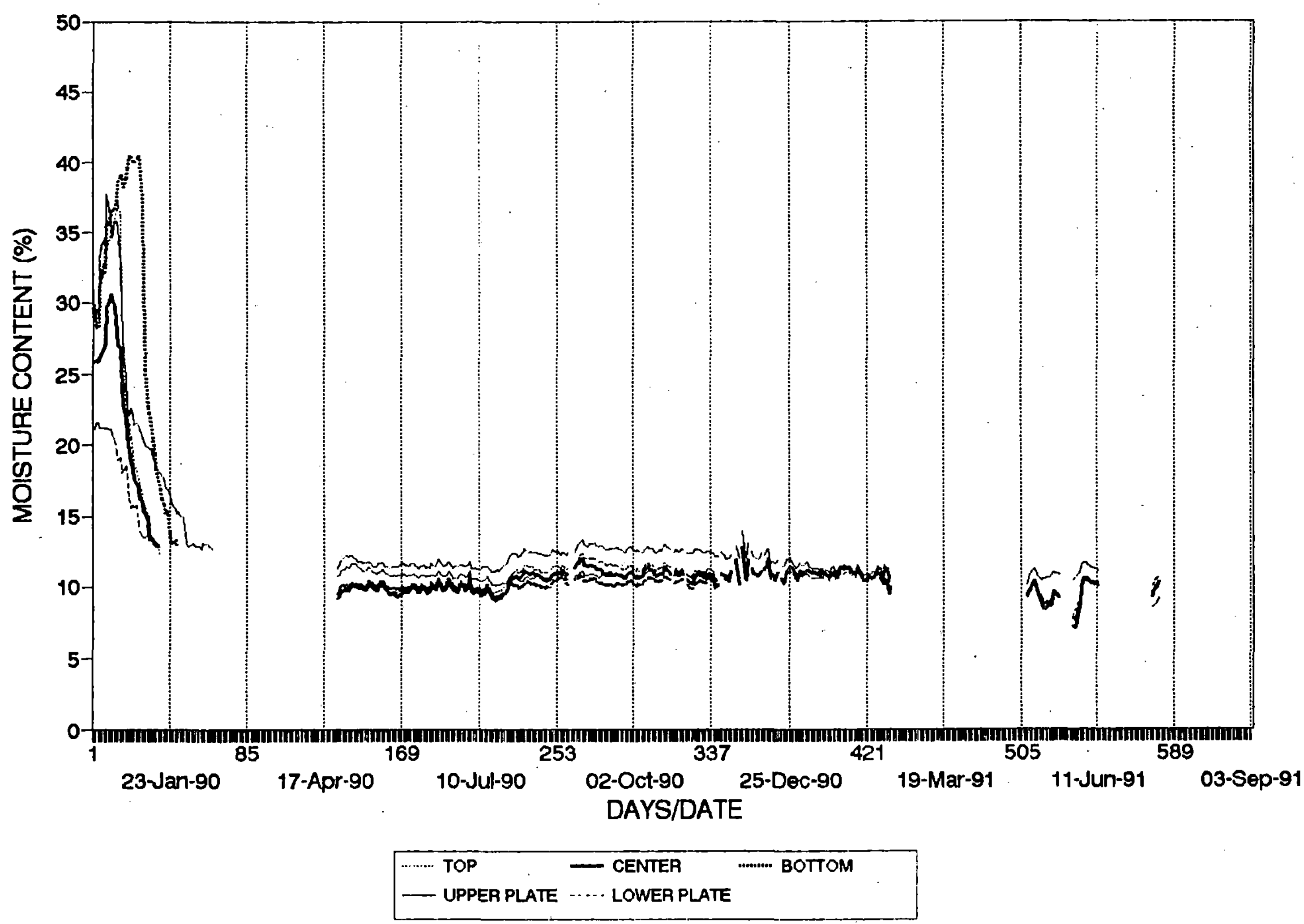
PANEL E1-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91

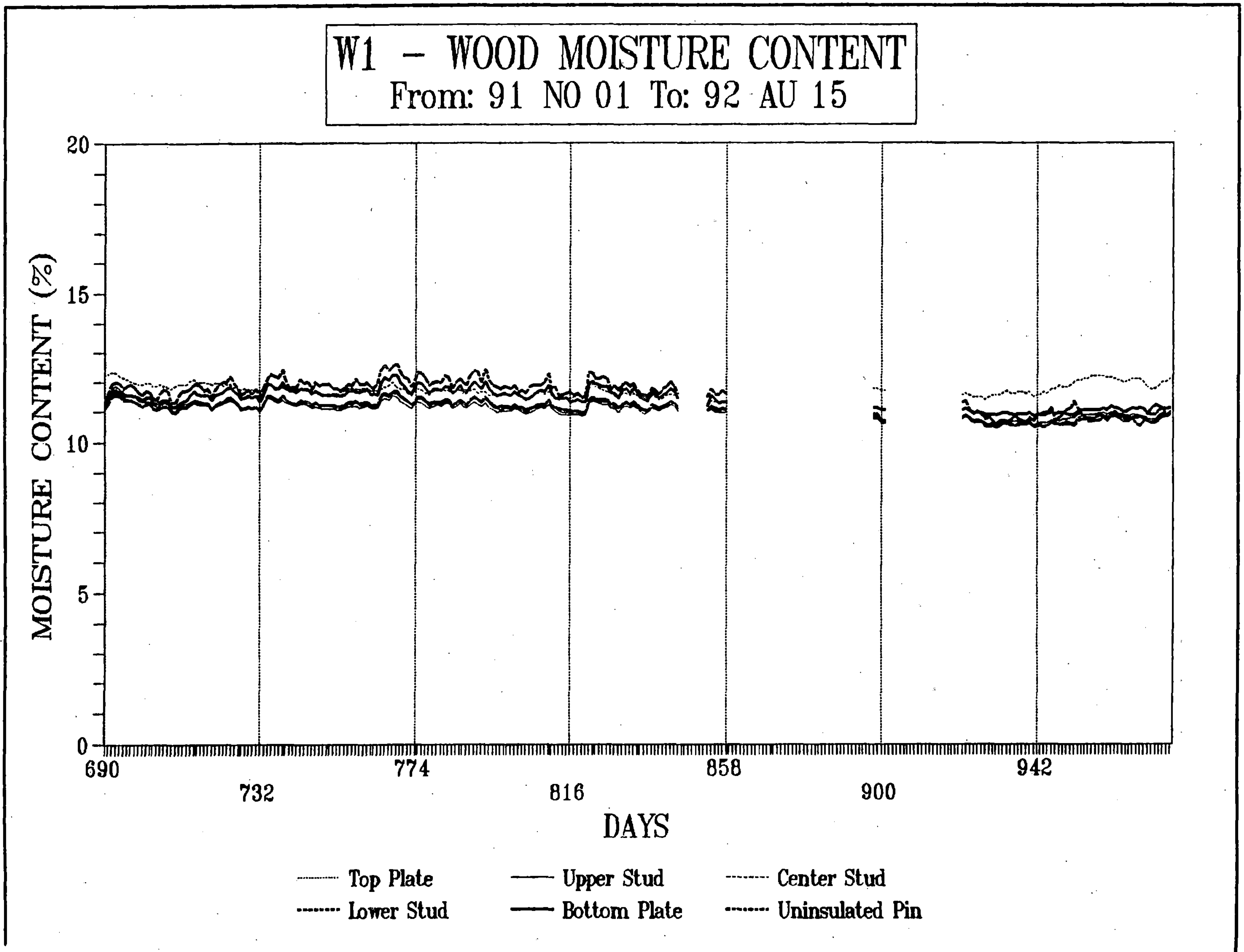




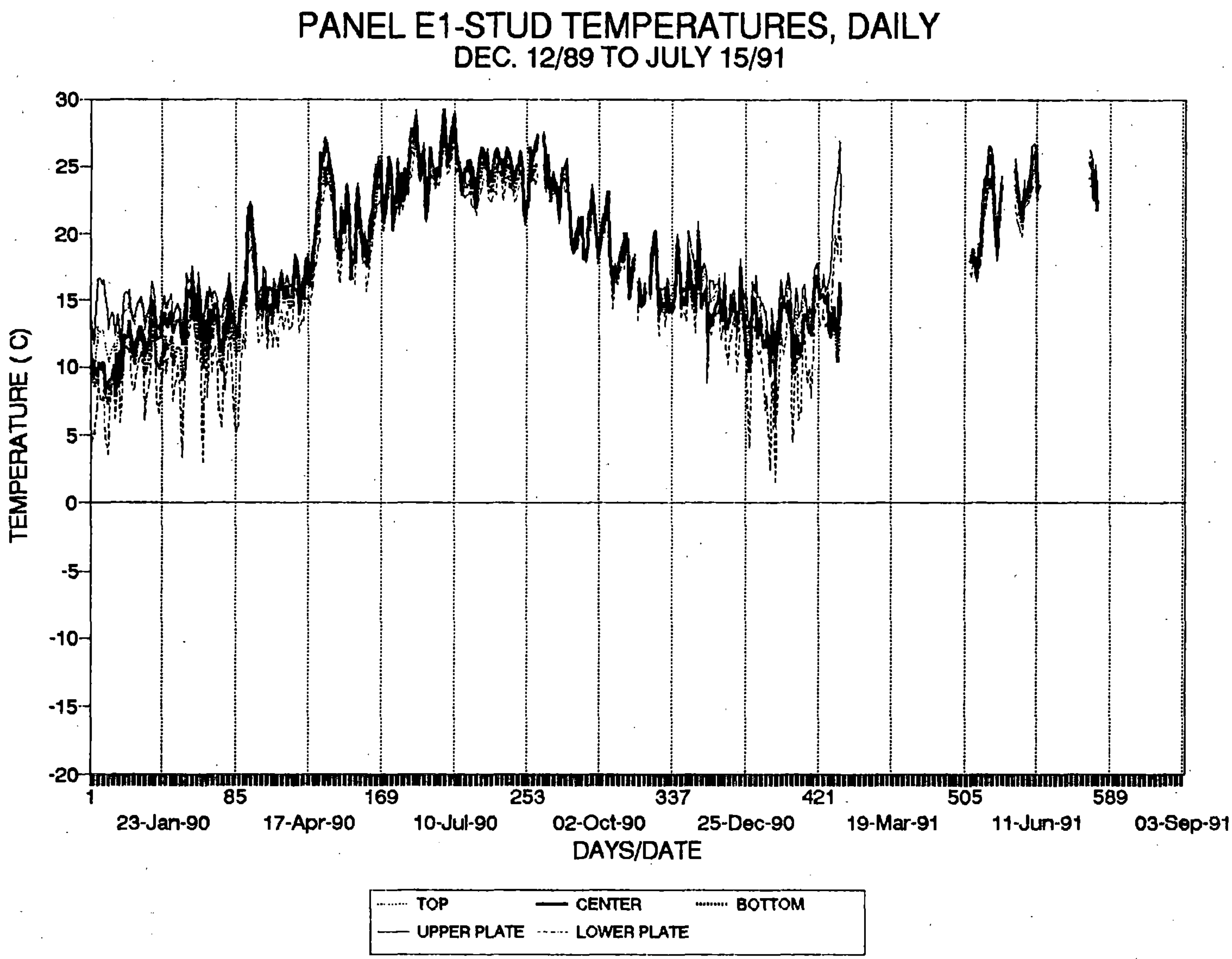
E1 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin

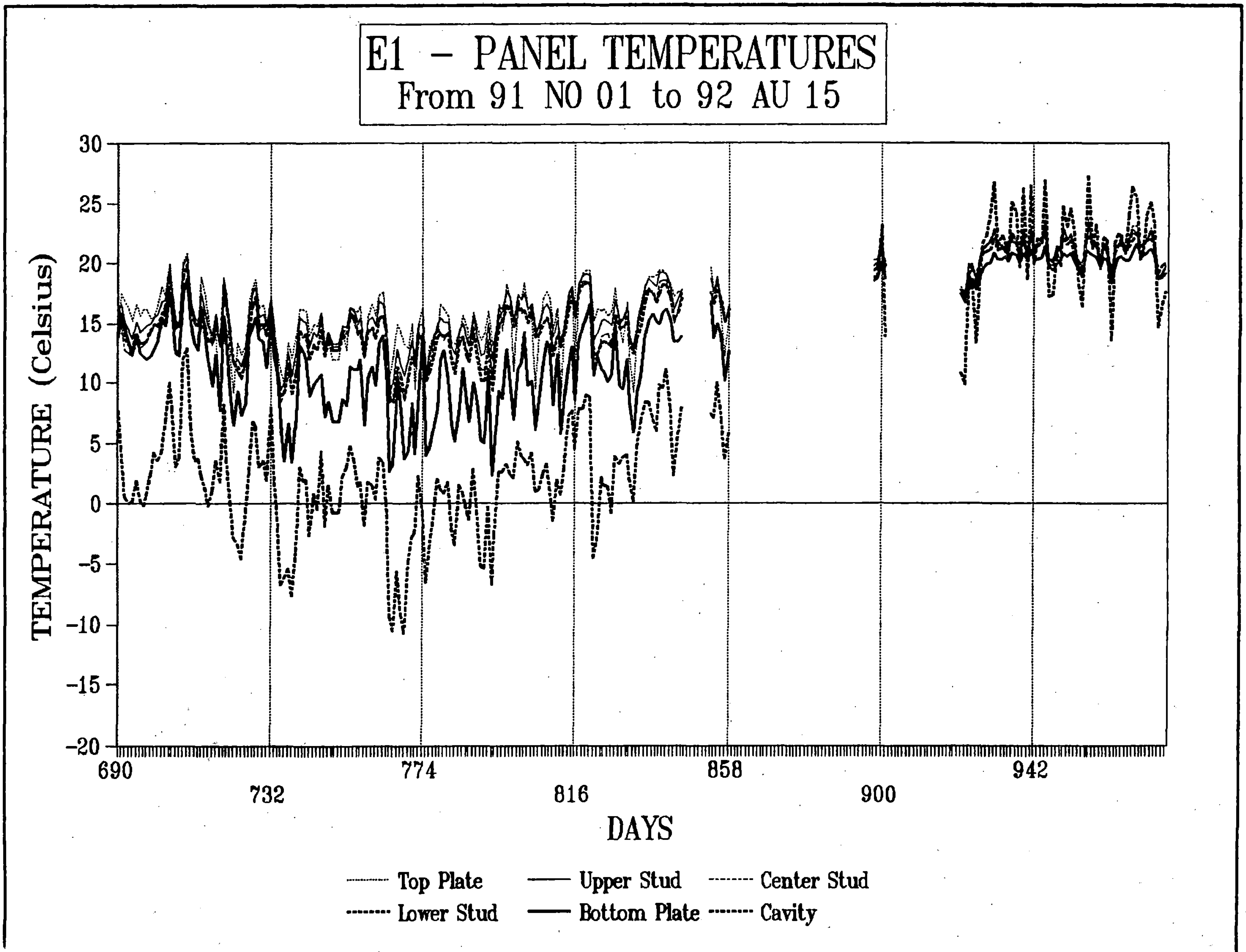
PANEL W1-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91

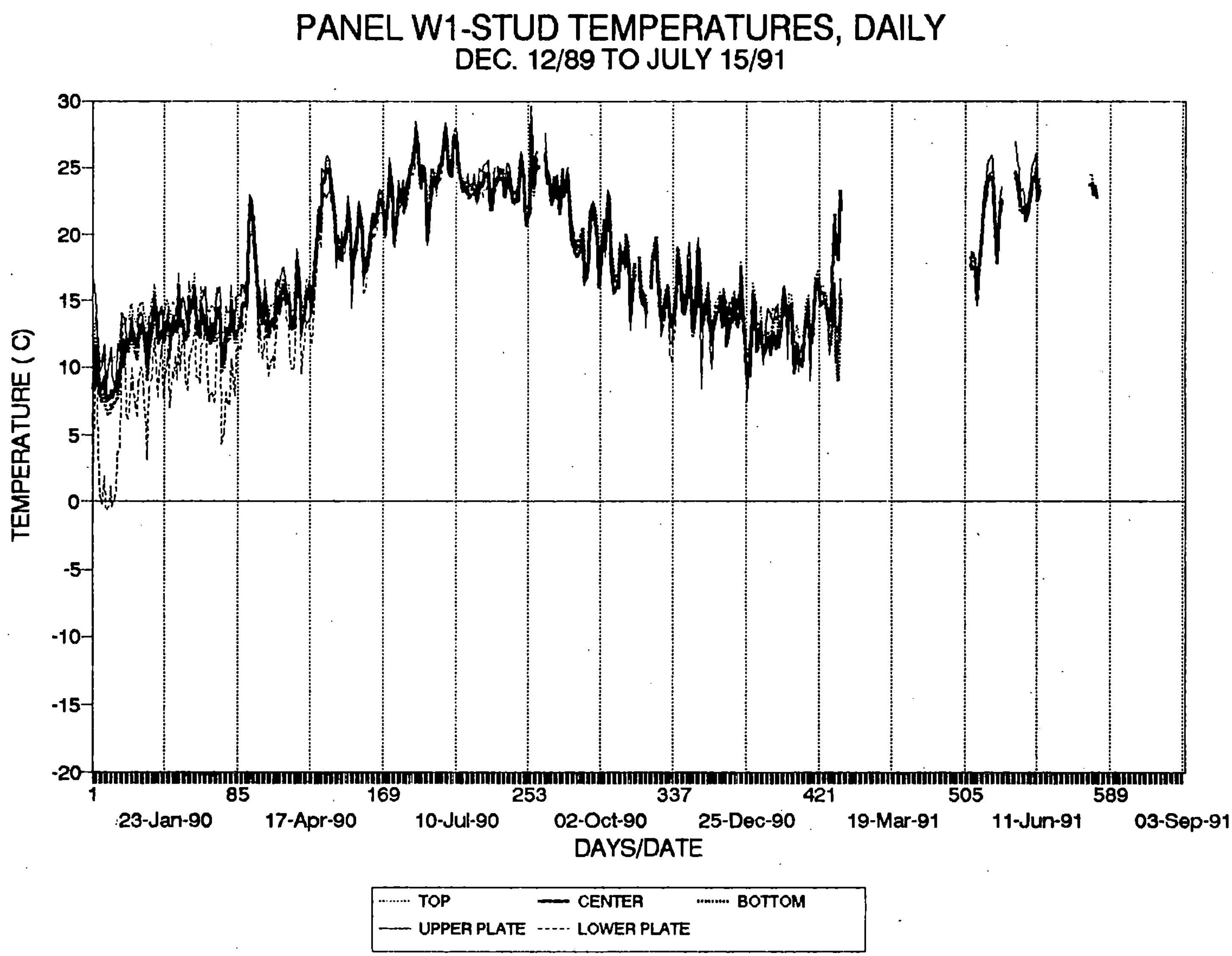




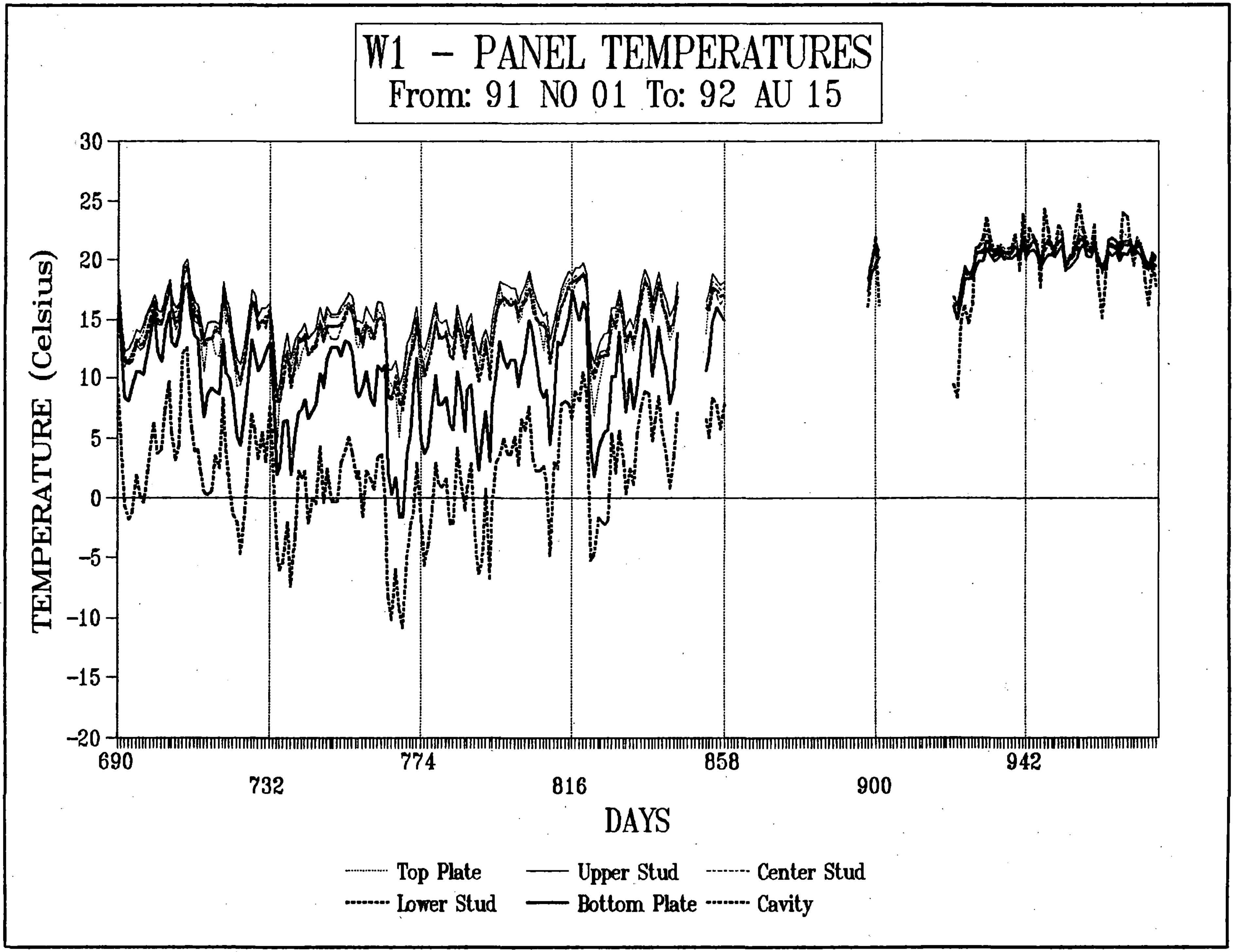
W1 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin


PANEL E1-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

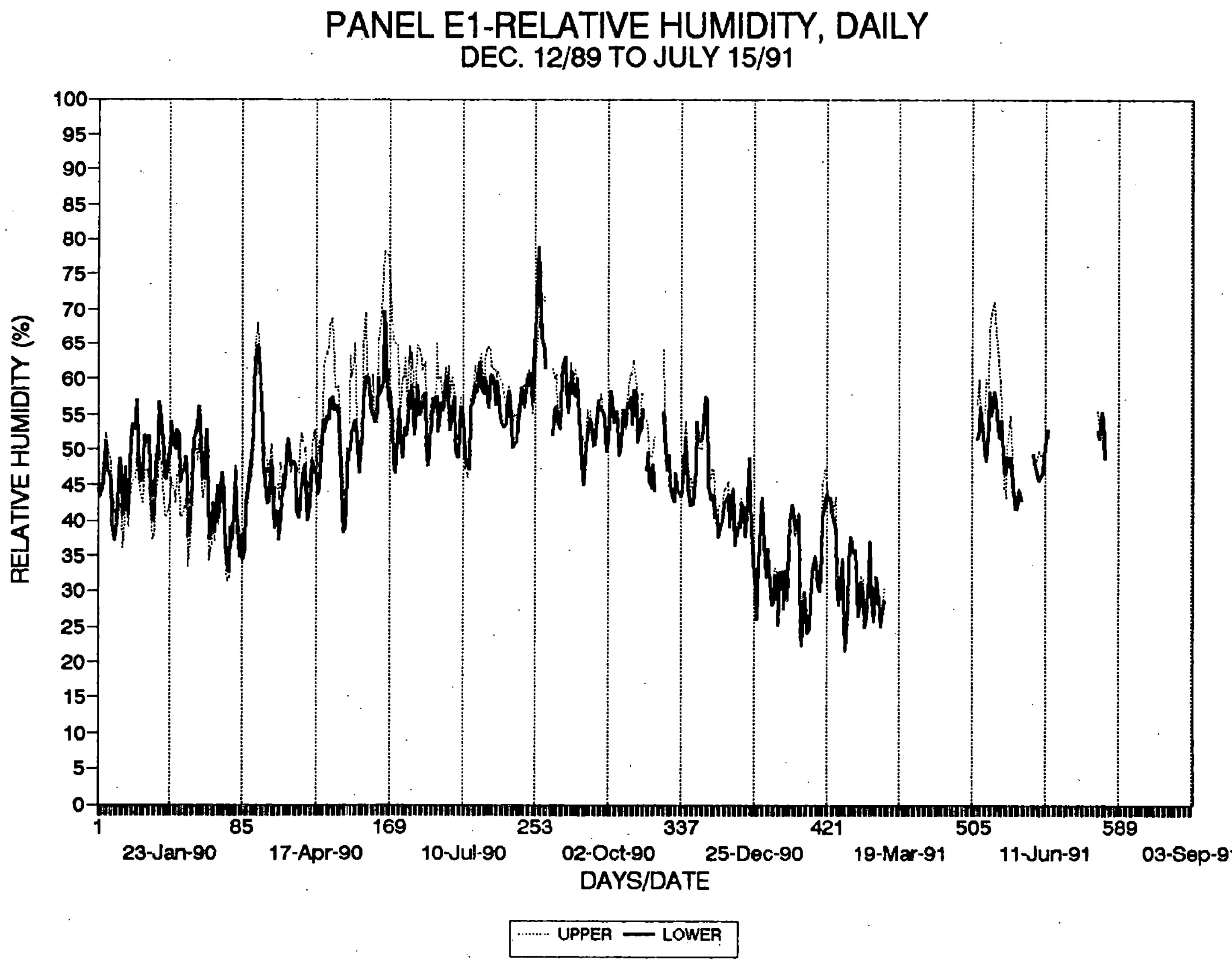

E1 - PANEL TEMPERATURES
From 91 NO 01 to 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Cavity



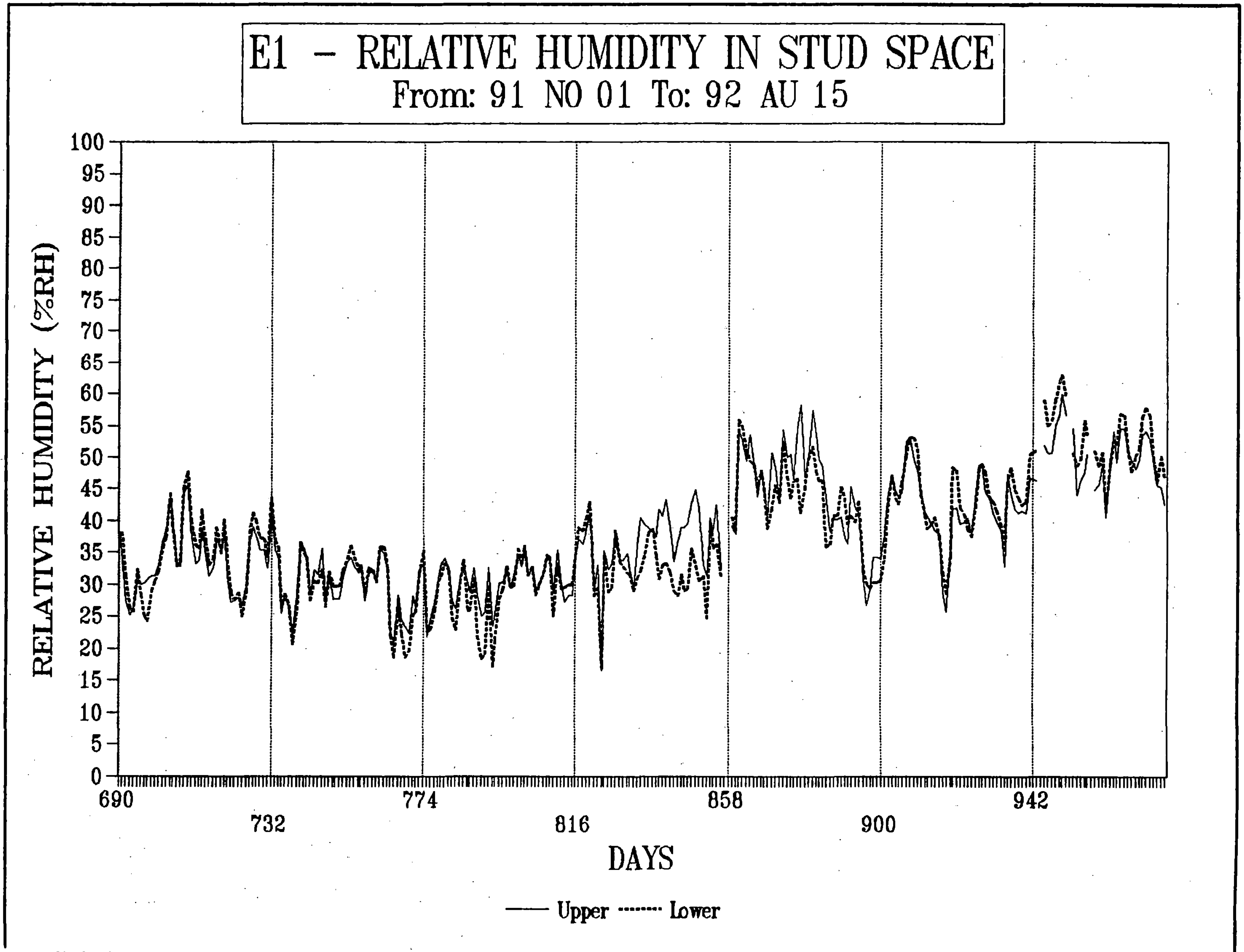
PANEL W1-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

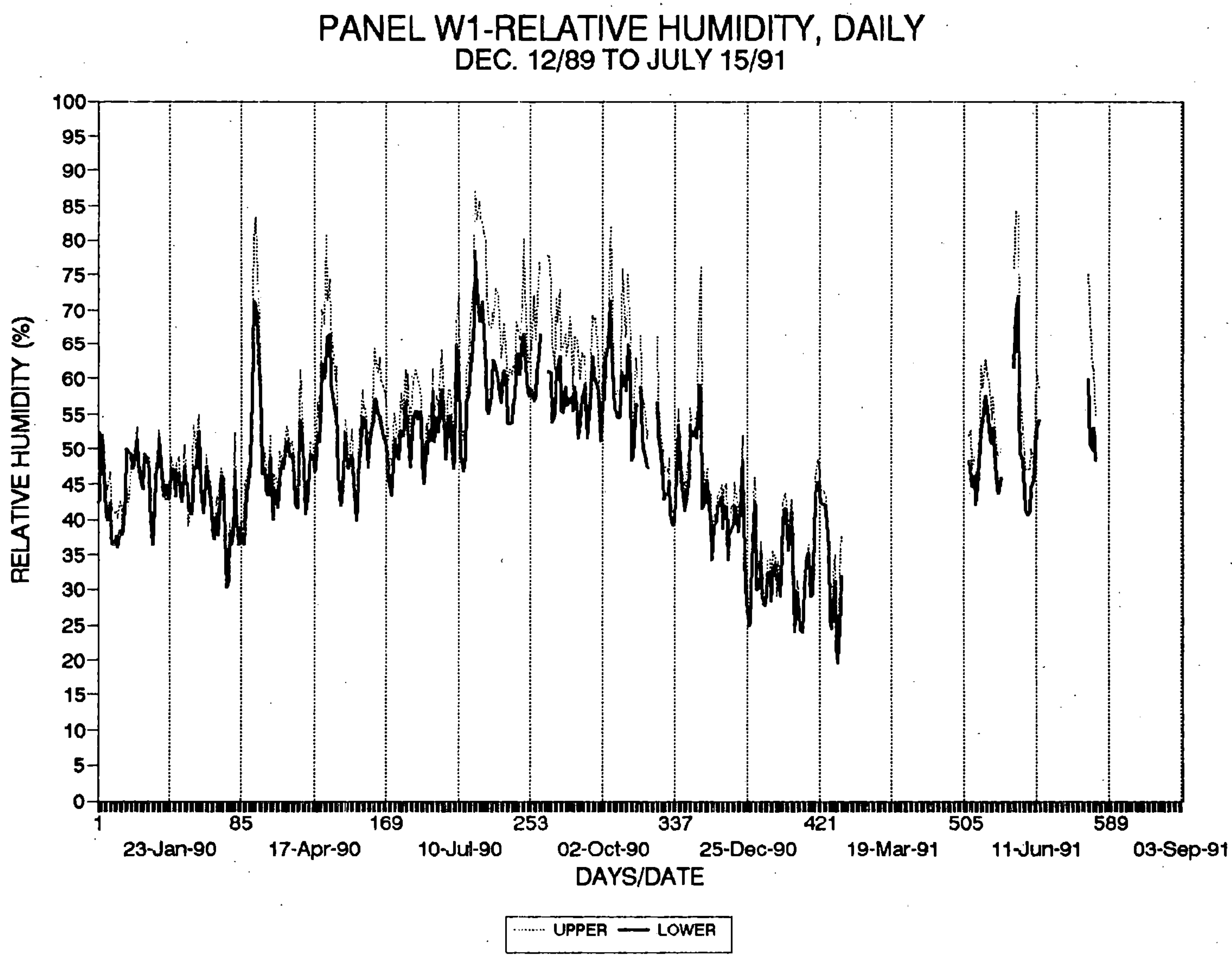


W1 - PANEL TEMPERATURES
From: 91 NO 01 To: 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Cavity

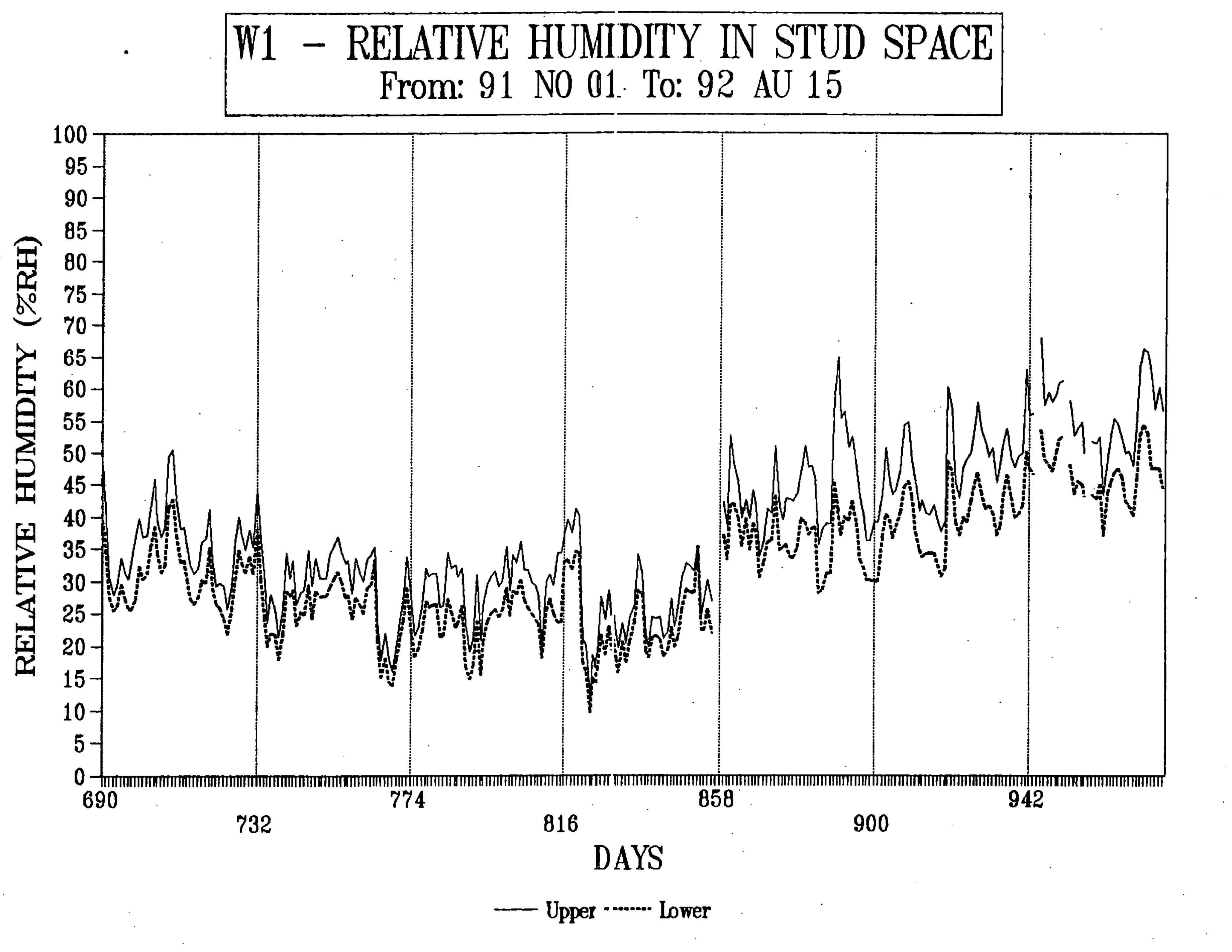


PANEL E1-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER


E1 - RELATIVE HUMIDITY IN STUD SPACE
From: 91 NO 01 To: 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower



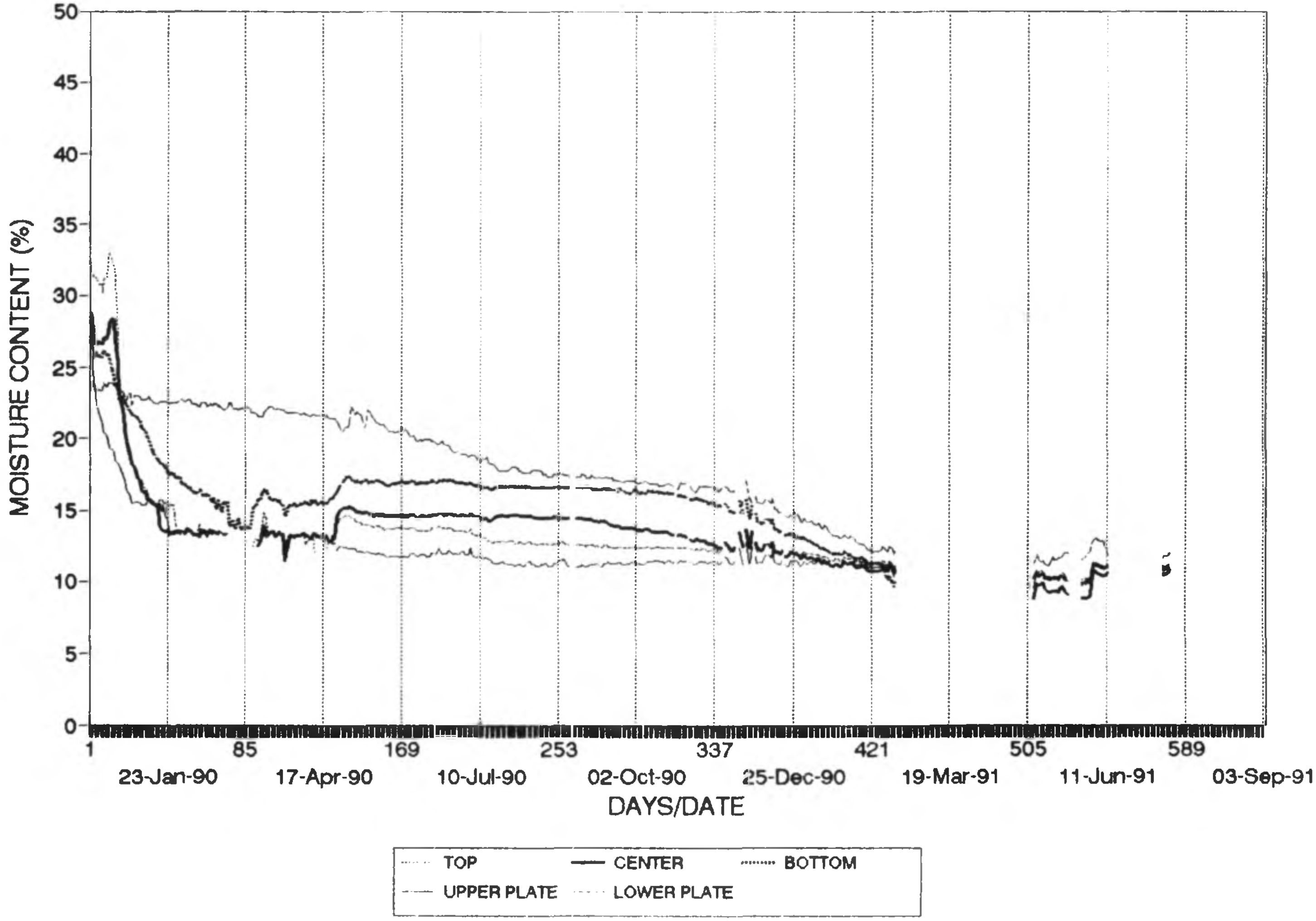
PANEL W1-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER

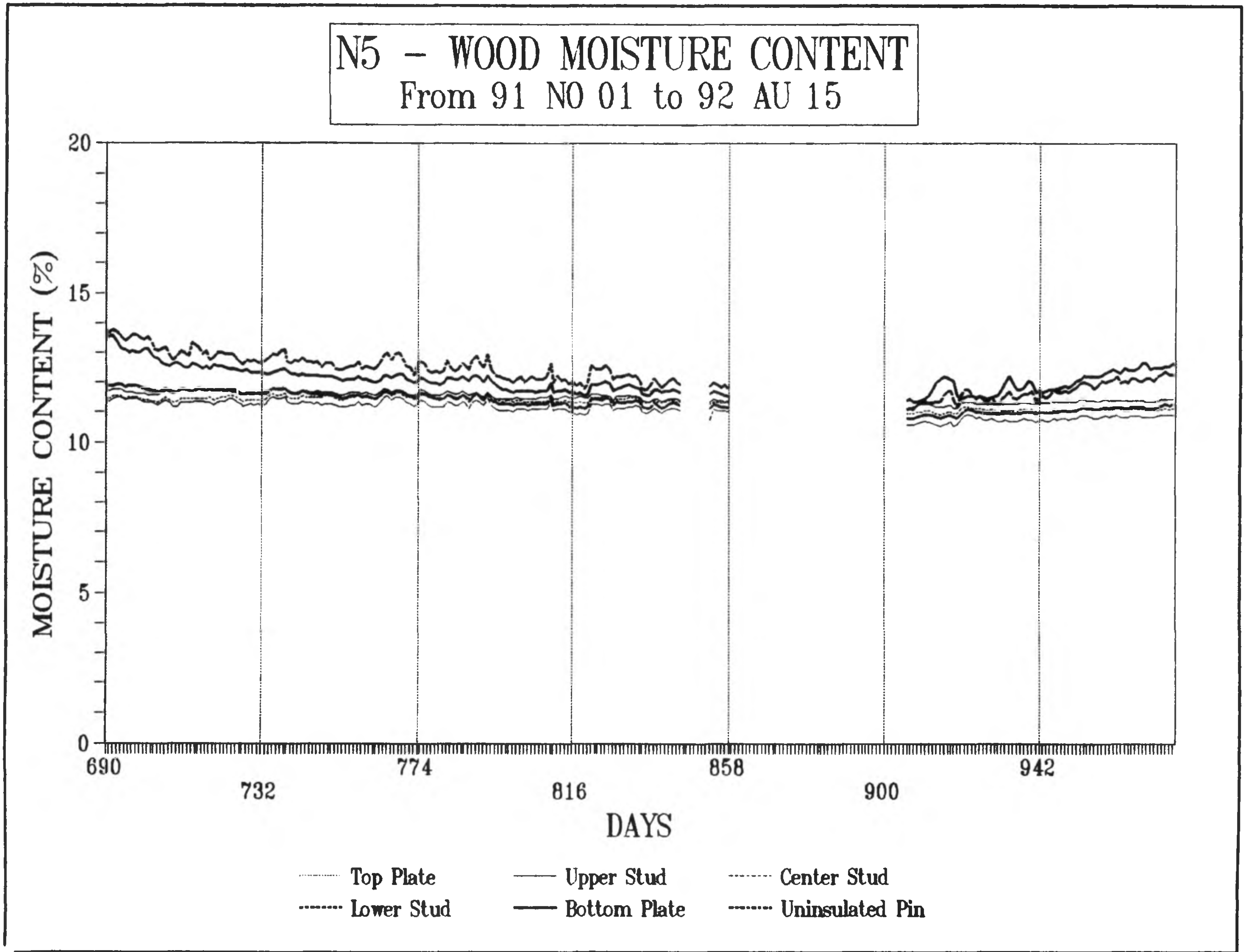


W1 - RELATIVE HUMIDITY IN STUD SPACE
From: 91 NO 01 To: 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower

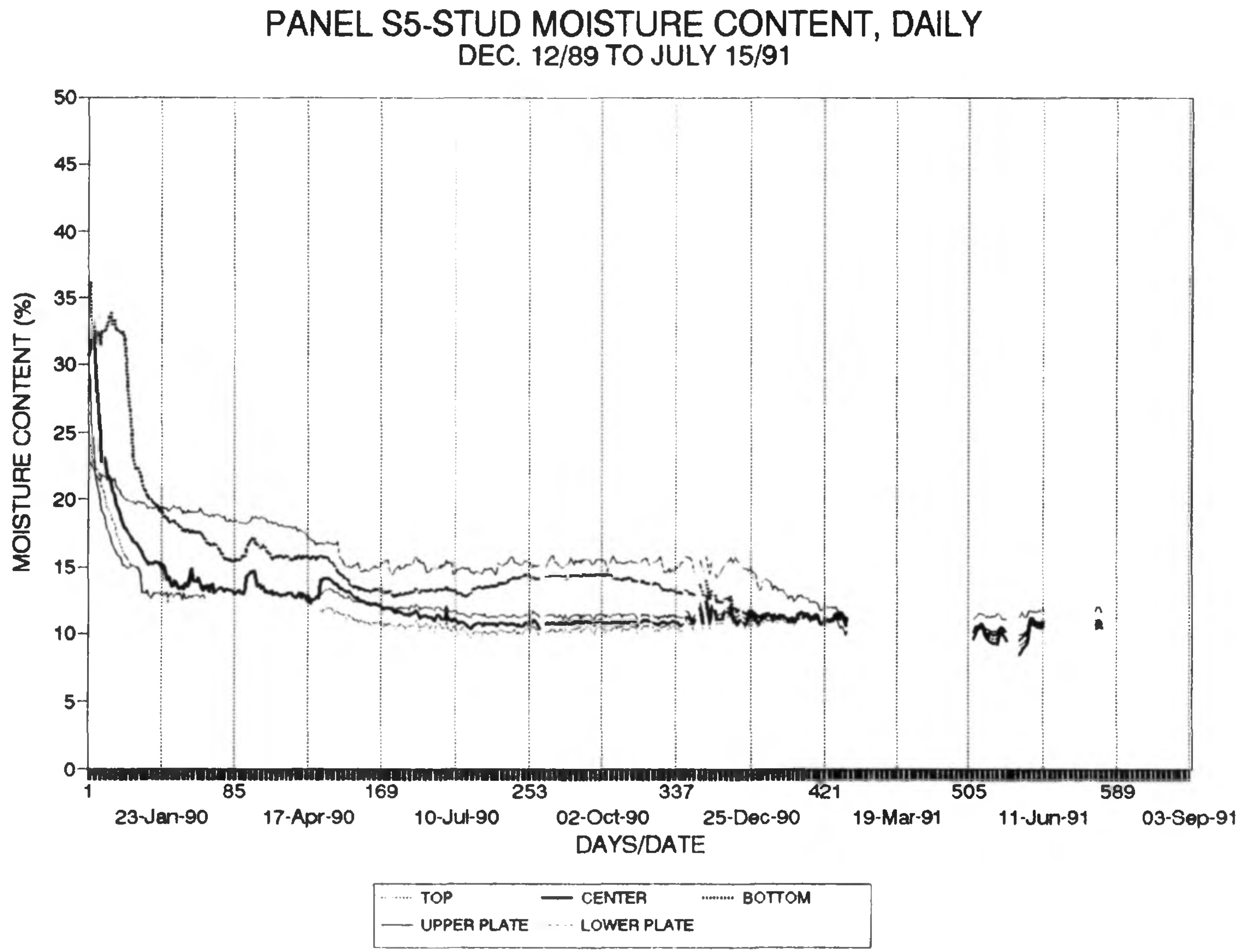
APPENDIX D: PANELS N5,S5

PANEL N5-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91

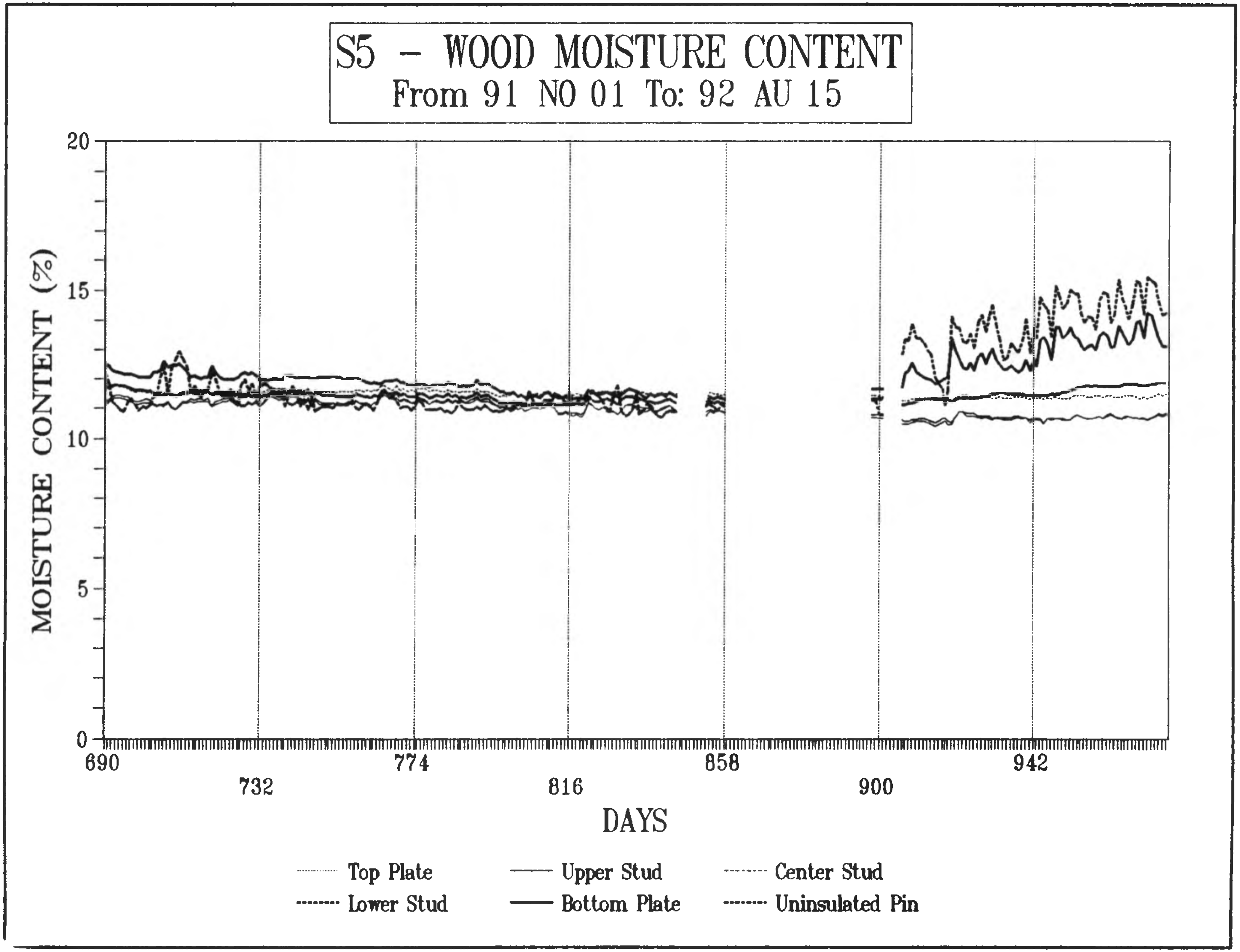


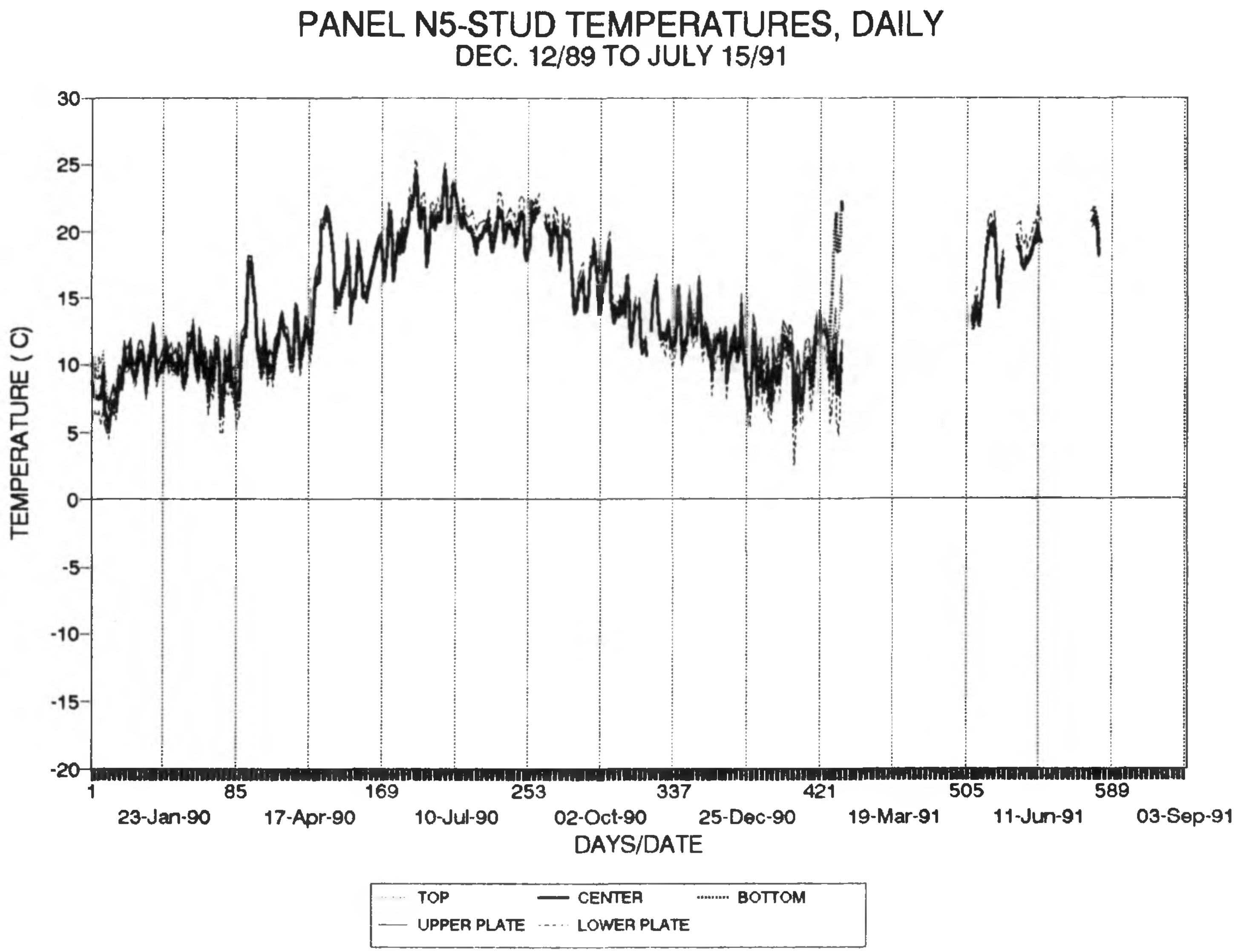


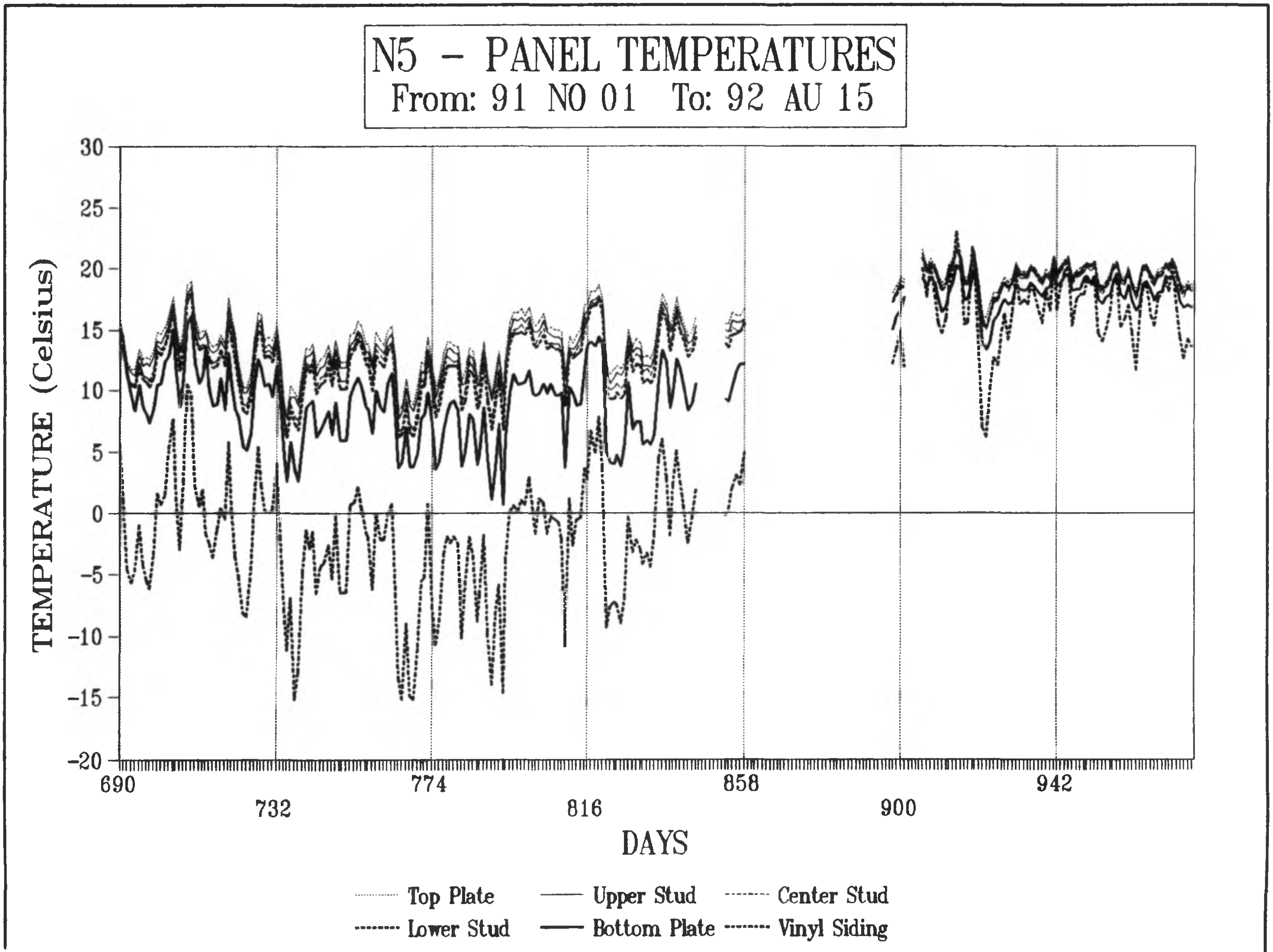
N5 - WOOD MOISTURE CONTENT
From 91 NO 01 to 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin



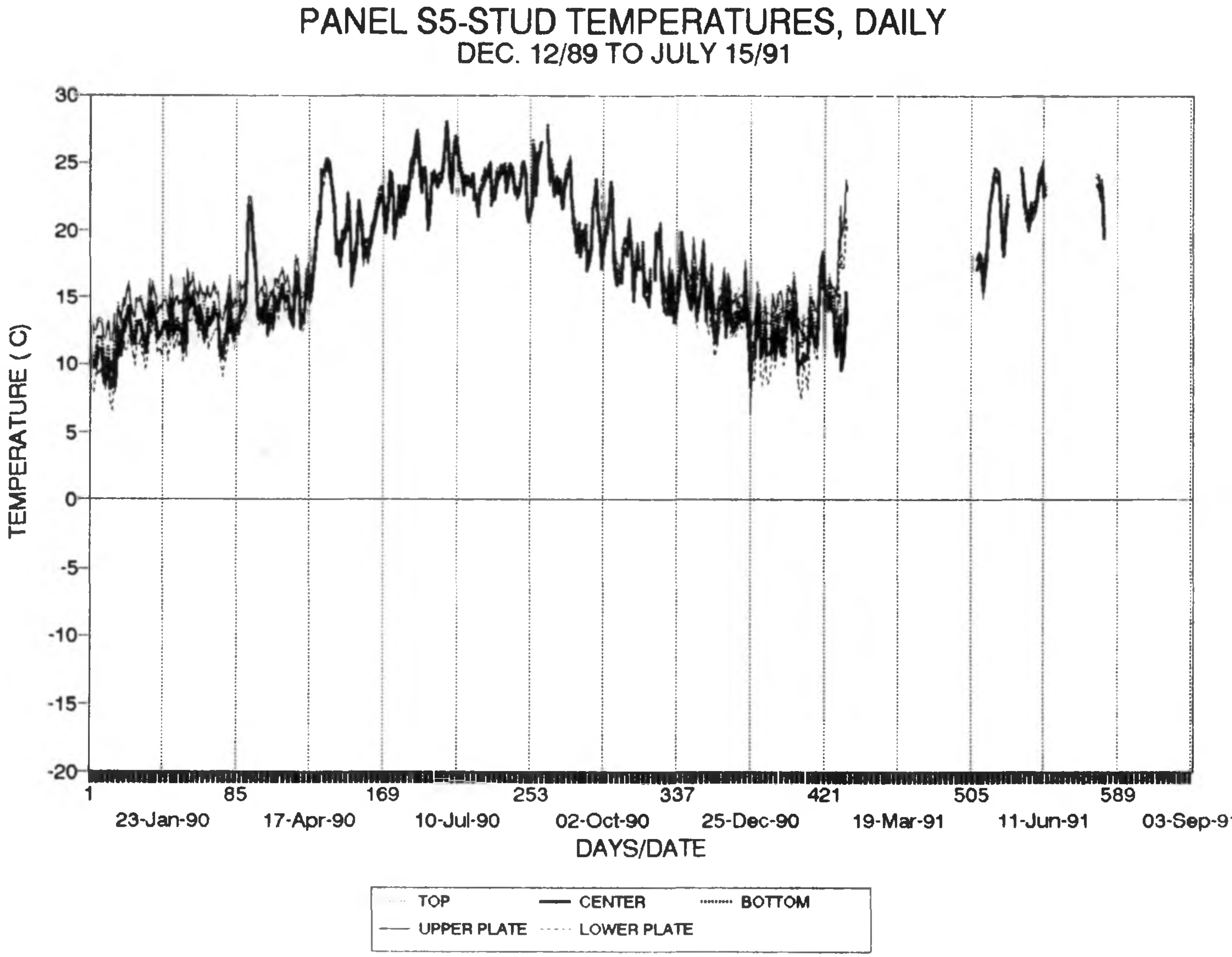
PANEL S5-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE


S5 - WOOD MOISTURE CONTENT
From 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin

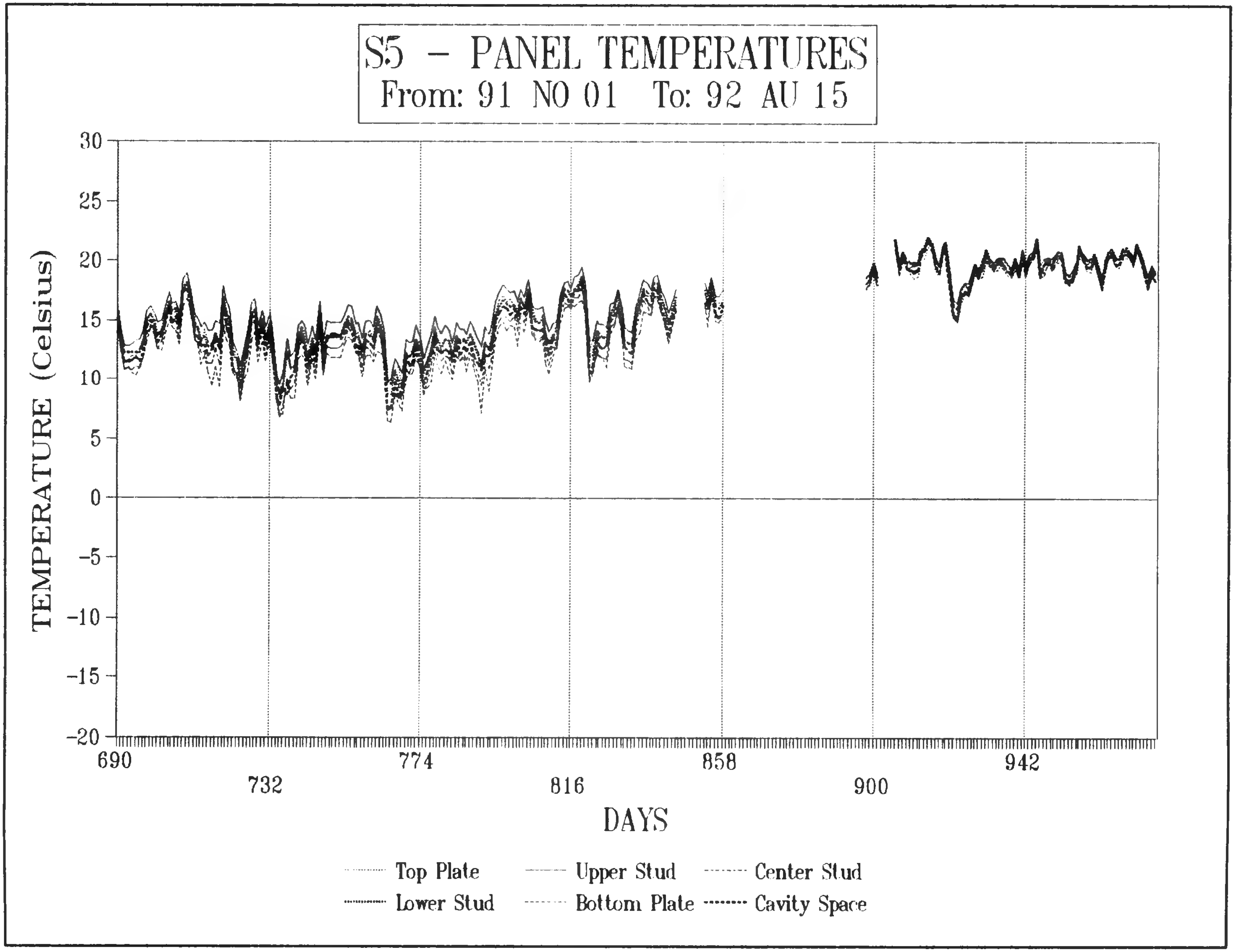

PANEL N5-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
30
25
20
15
10
5
0
-5
-10
-15
-20
TEMPERATURE (C)
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

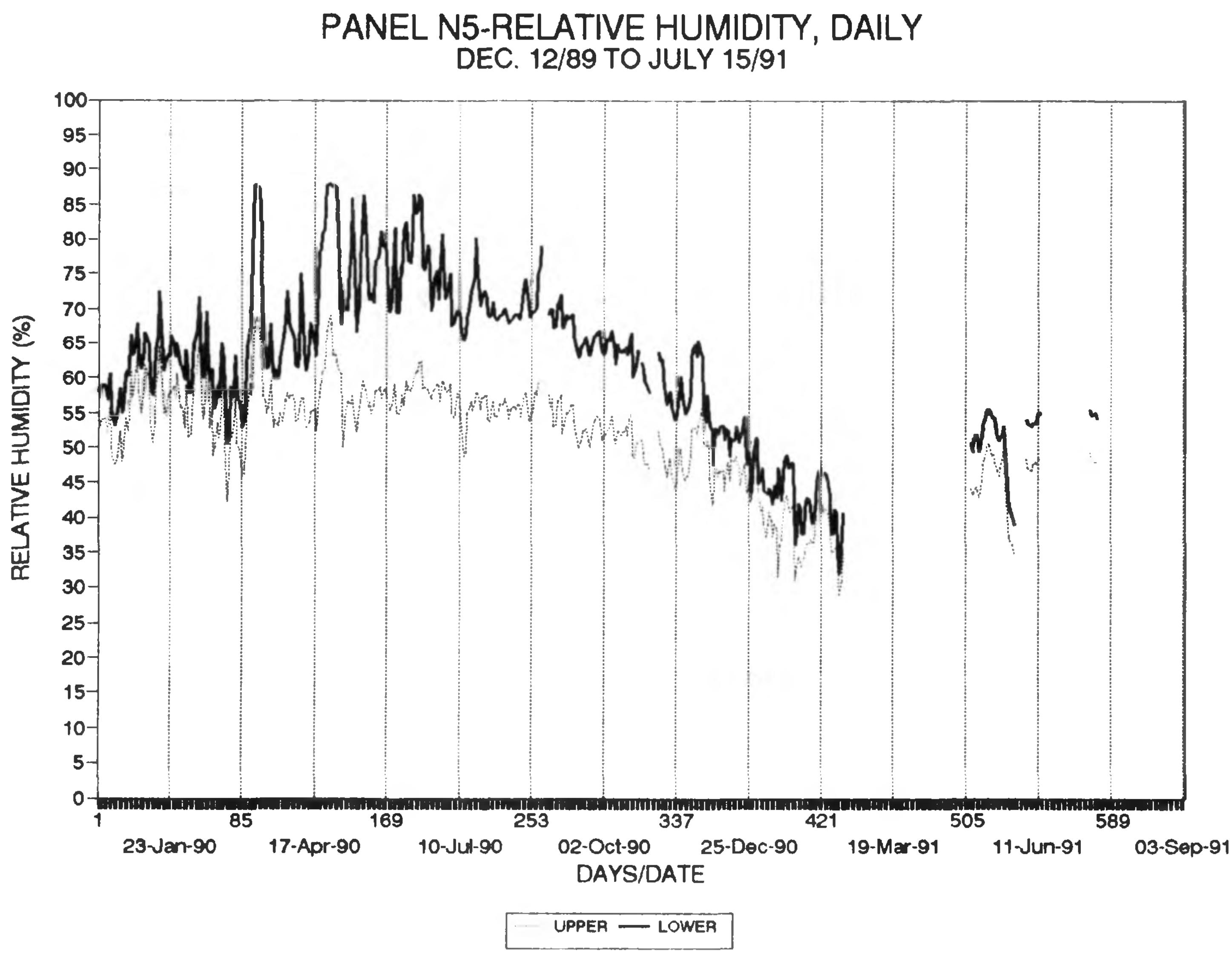


N5 - PANEL TEMPERATURES
From: 91 NO 01 To: 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Vinyl Siding

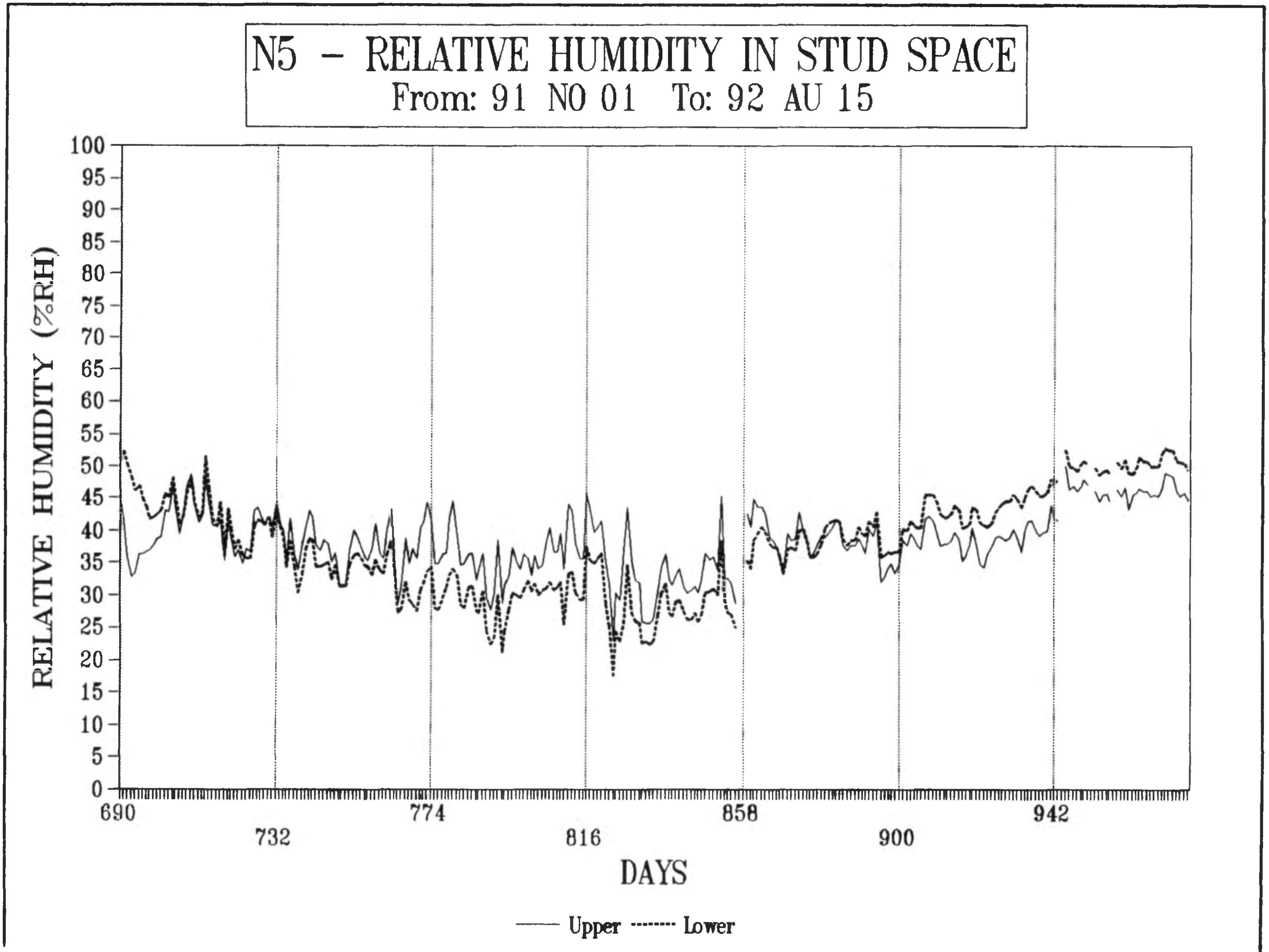


PANEL S5-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

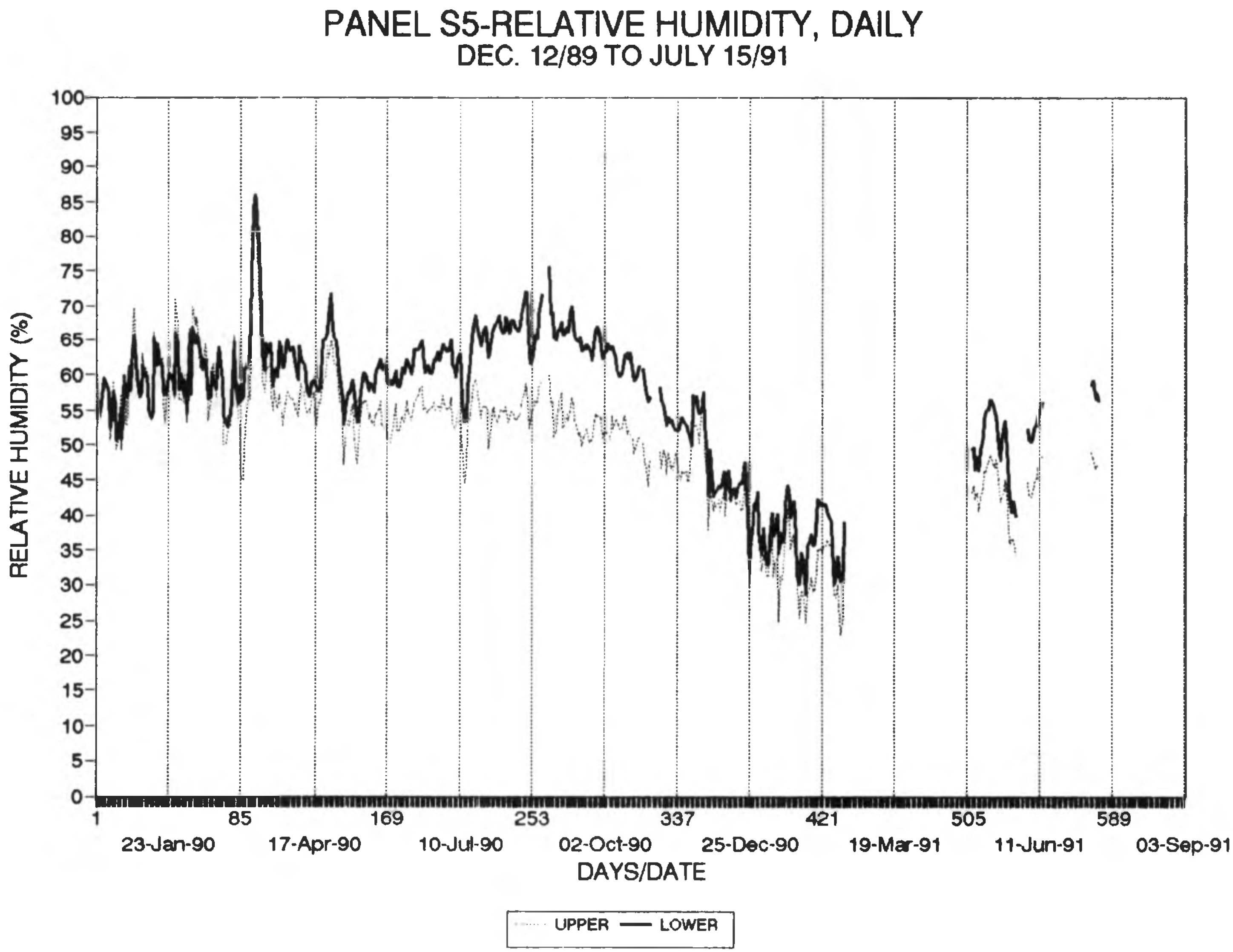

S5 - PANEL TEMPERATURES
From: 91 NO 01 To: 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Cavity Space



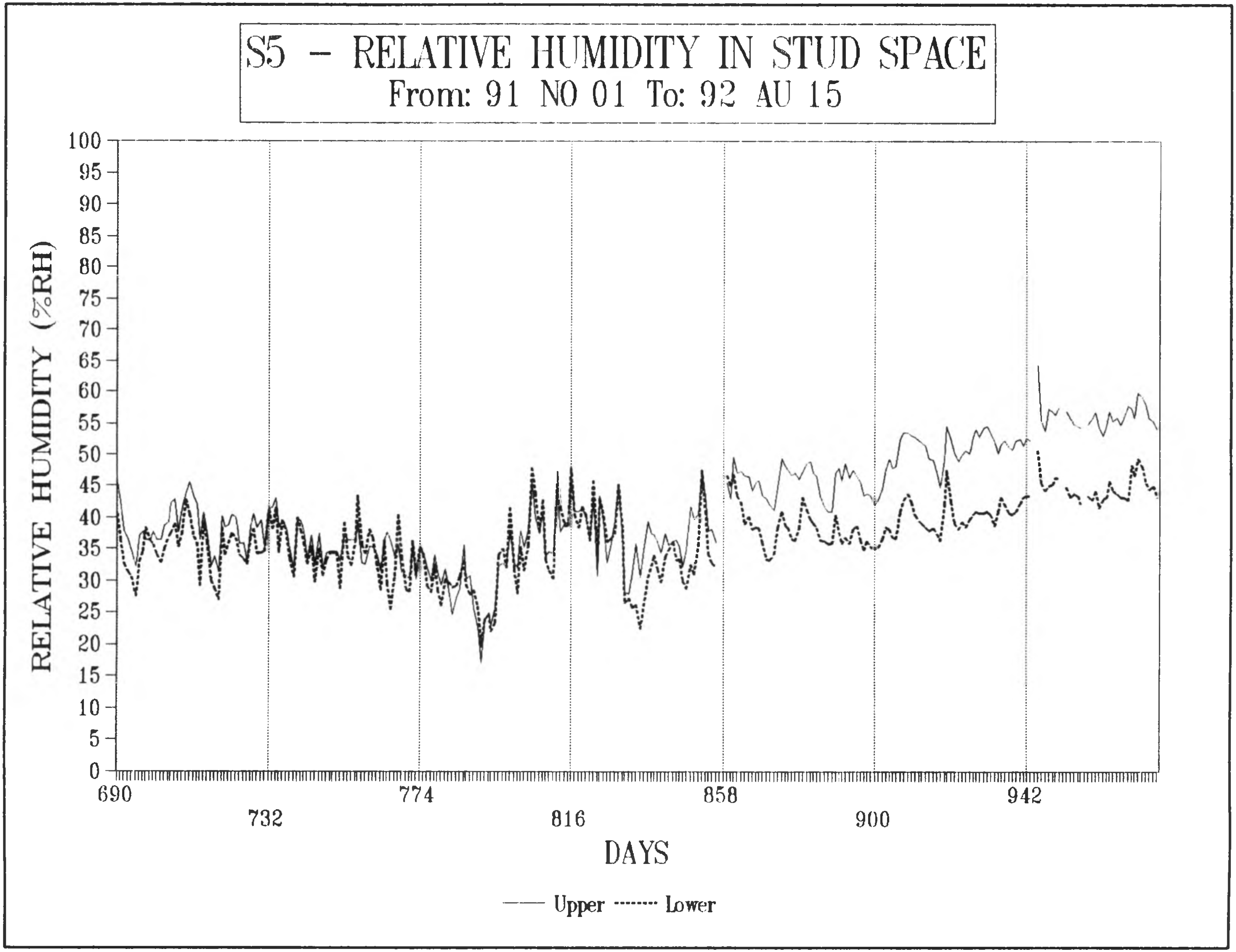
PANEL N5-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER



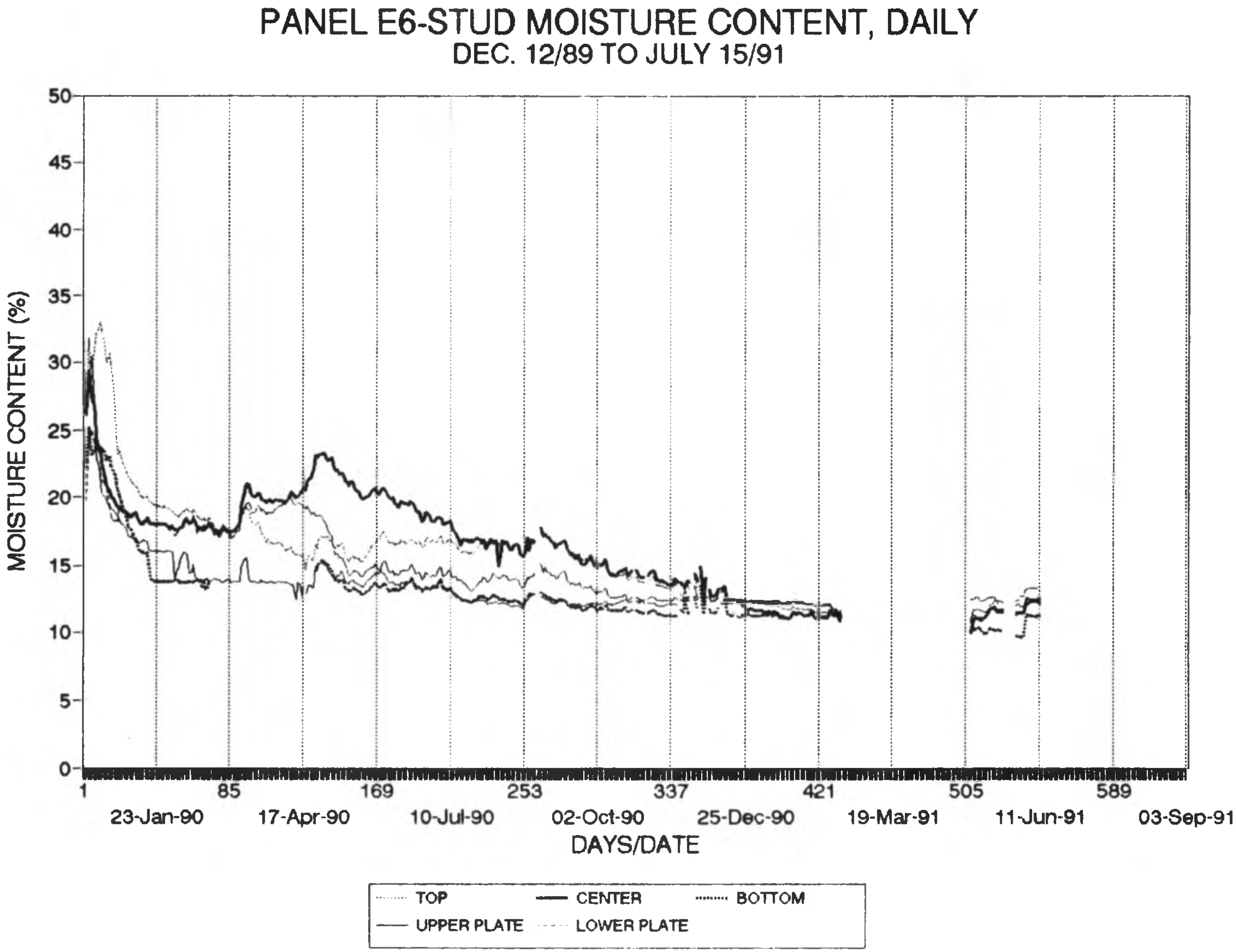
N5 - RELATIVE HUMIDITY IN STUD SPACE
From: 91 NO 01 To: 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower



PANEL S5-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER

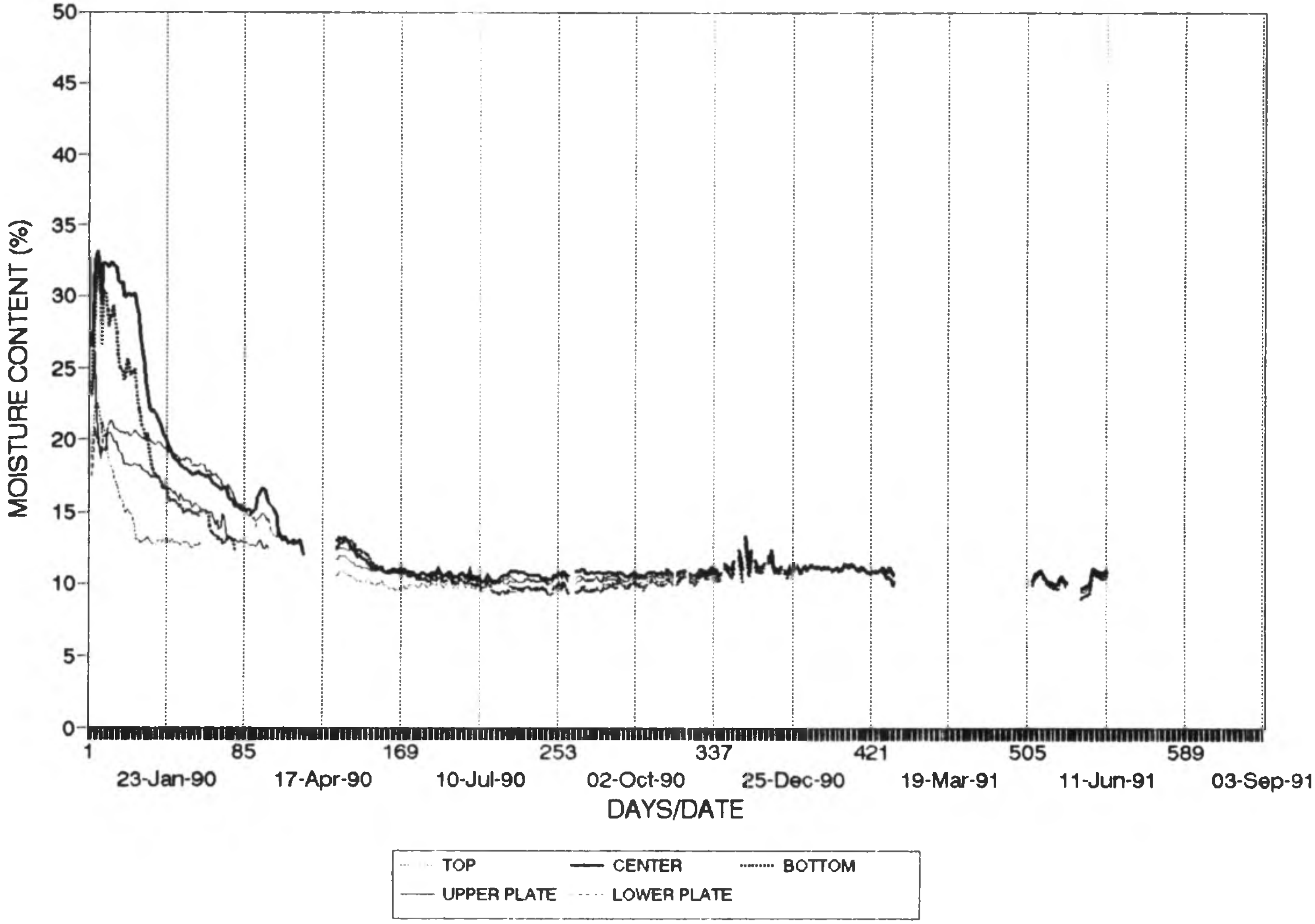

S5 - RELATIVE HUMIDITY IN STUD SPACE
From: 91 NO 01 To: 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower

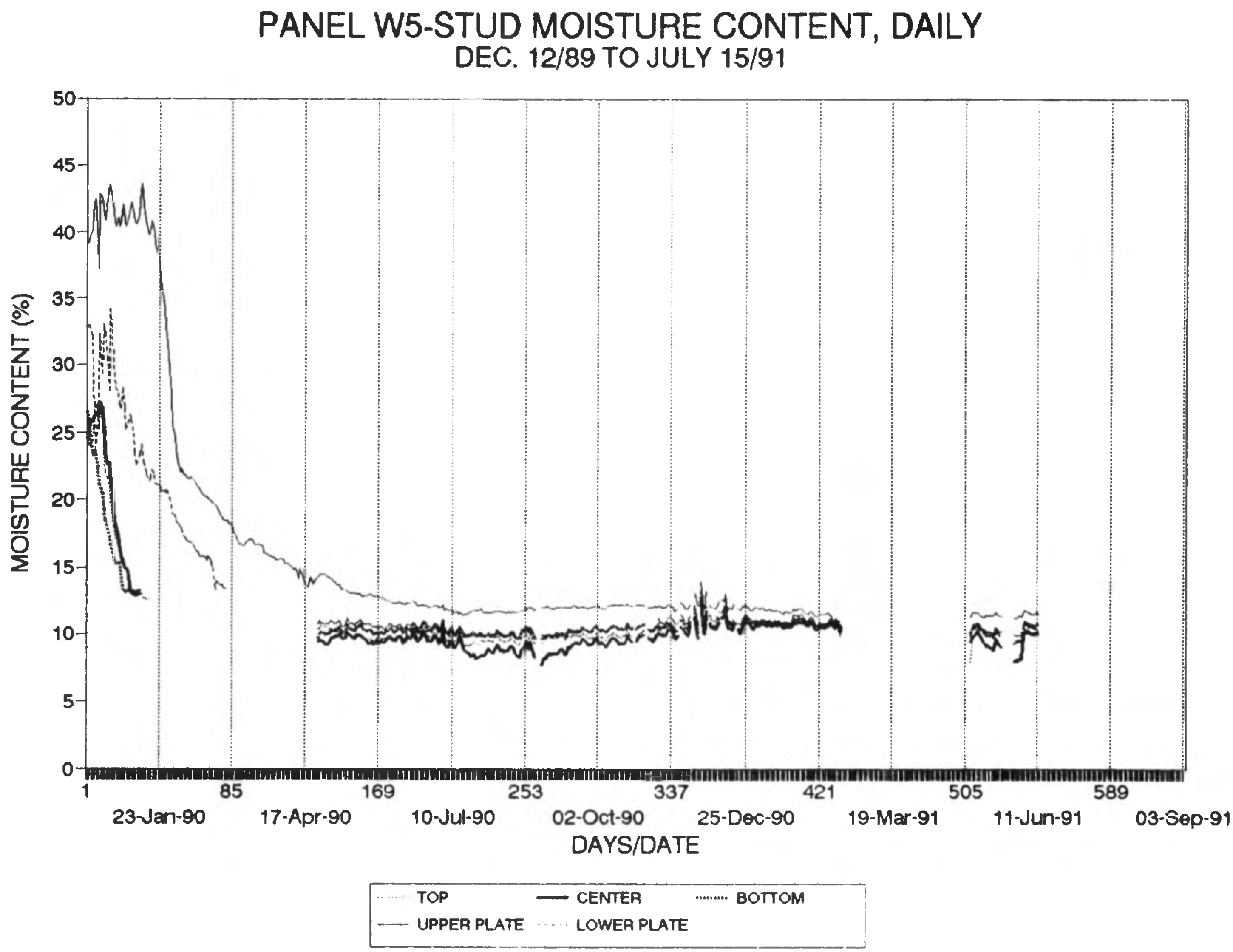
APPENDIX E: PANELS E6,W6 AND W5

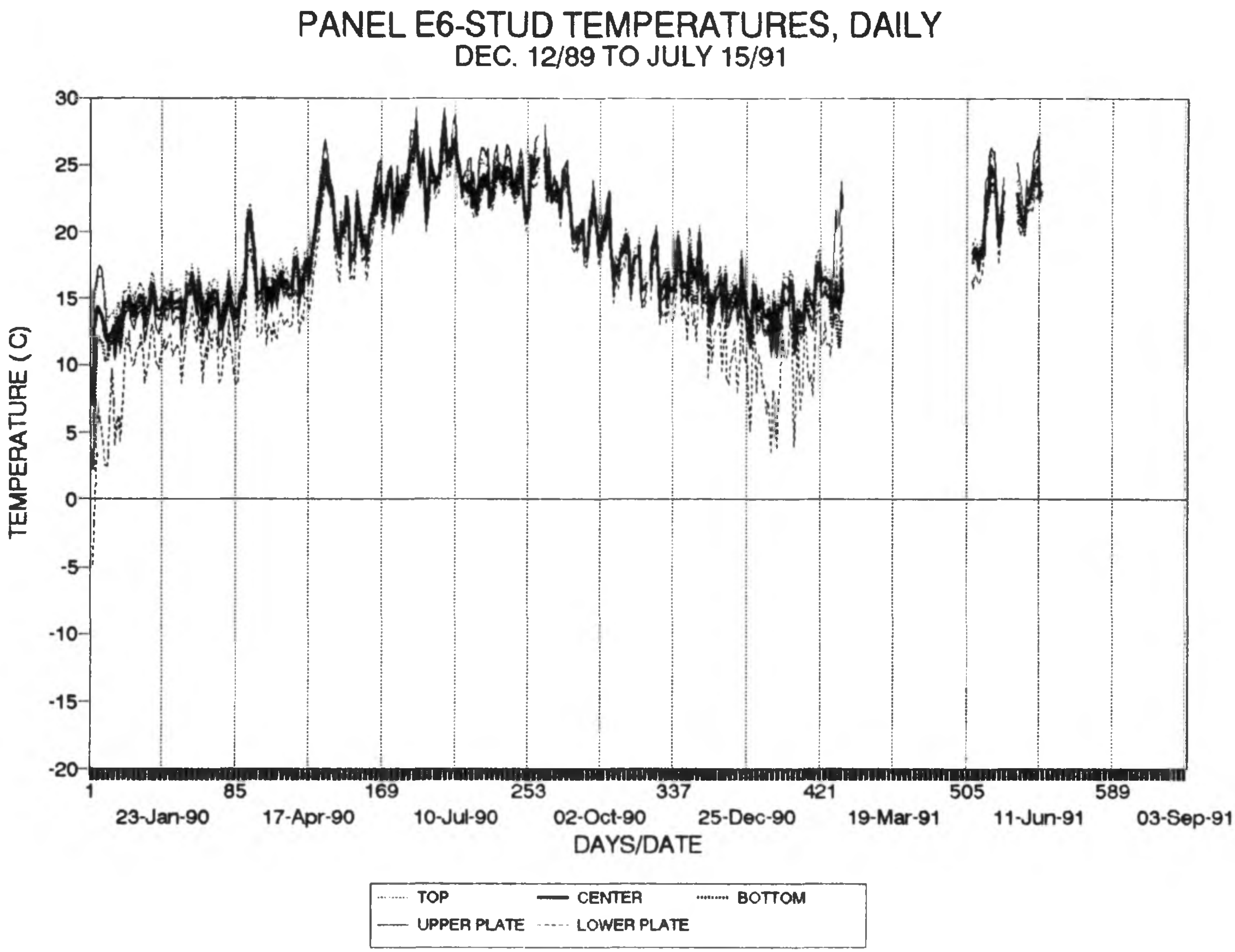


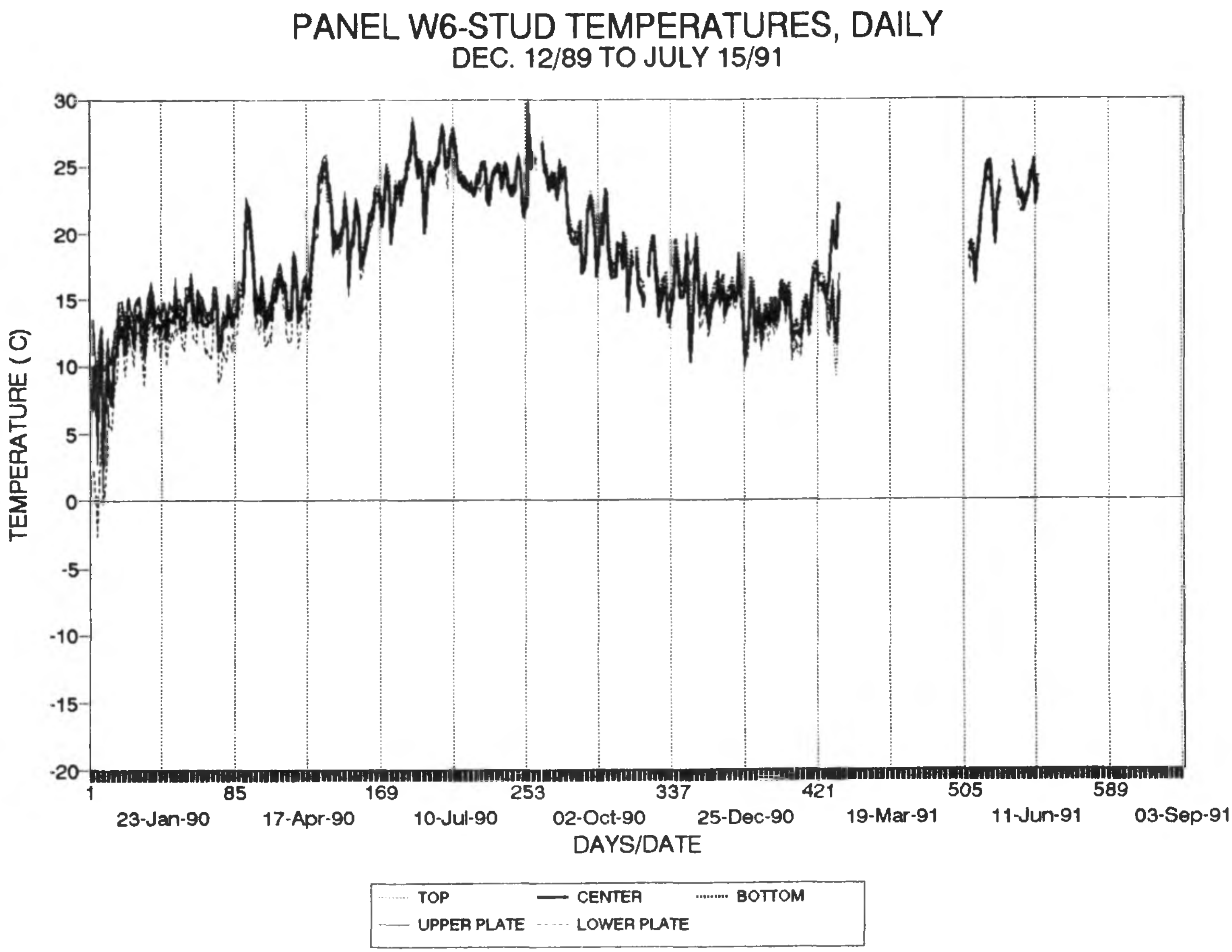
PANEL E6-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

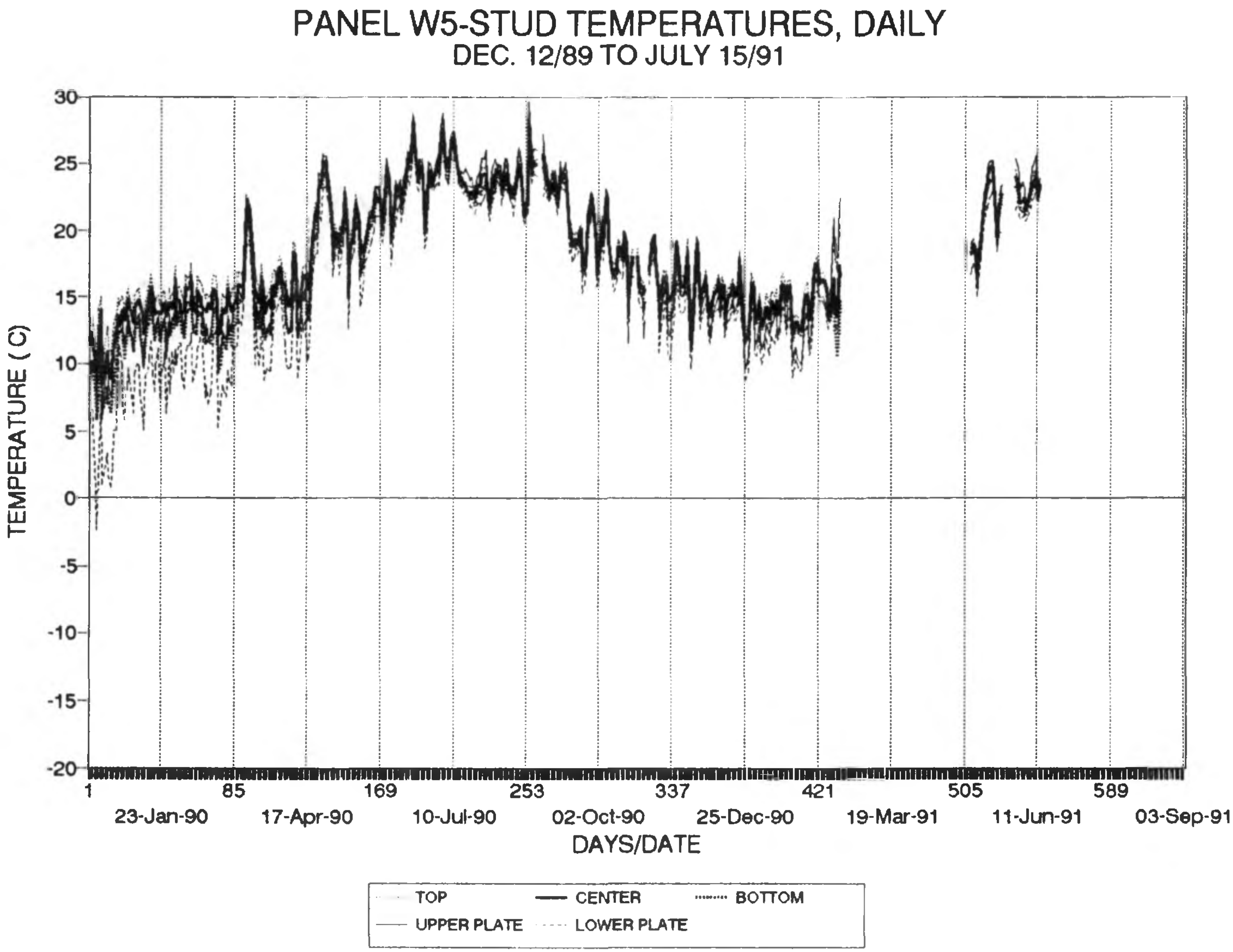
PANEL W6-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91



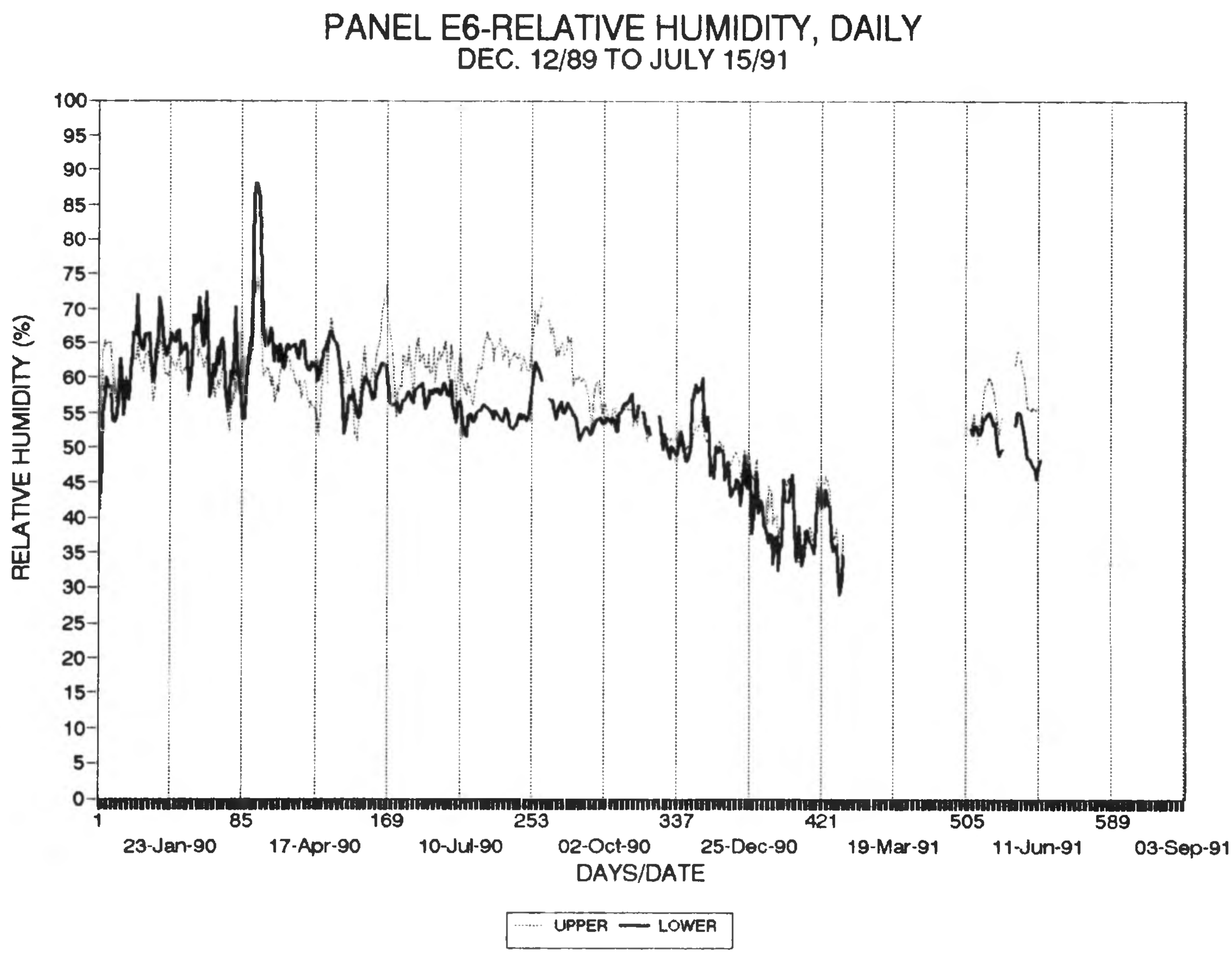

PANEL W5-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
0
5
10
15
20
25
30
35
40
45
50
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE


PANEL E6-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

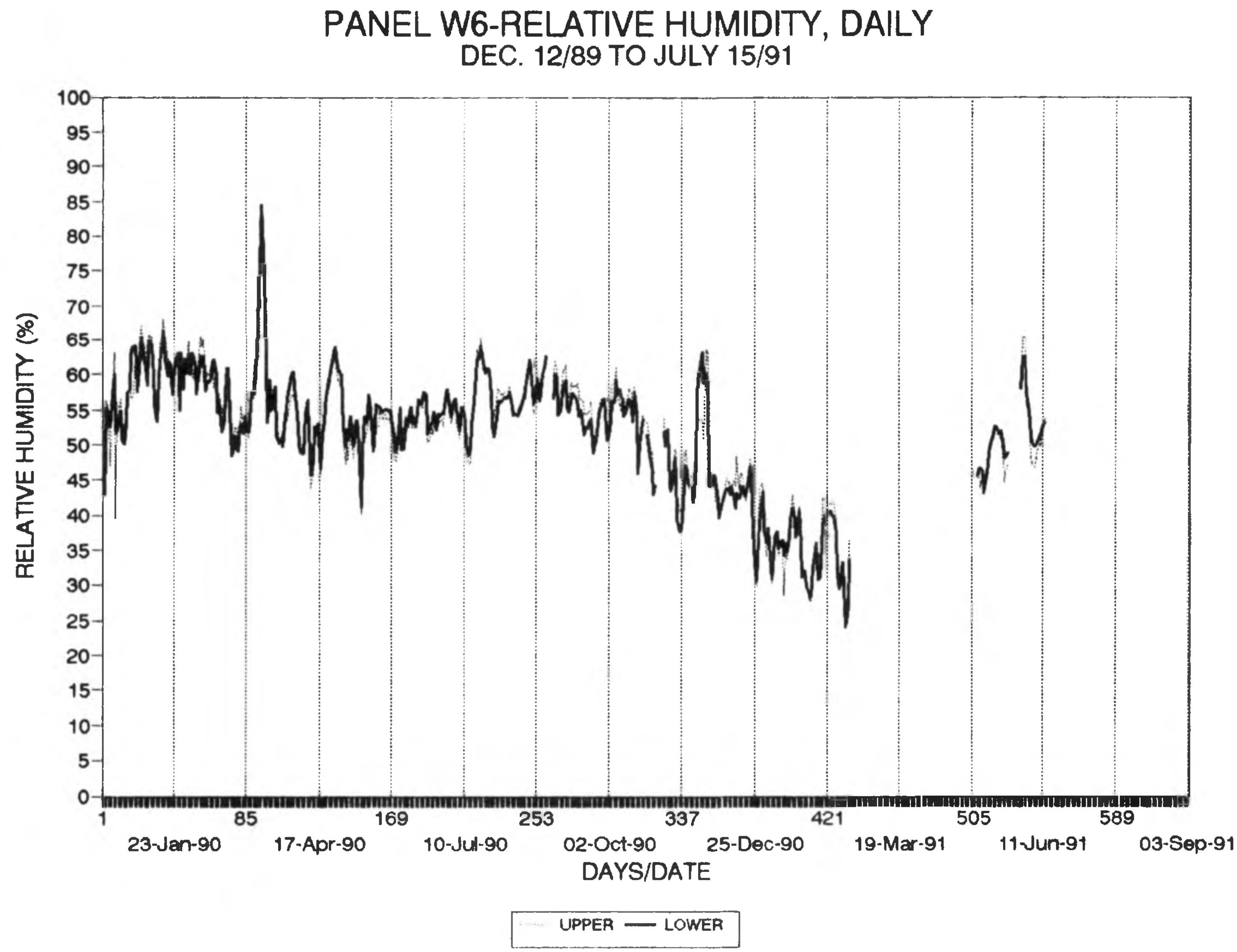

PANEL W6-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE



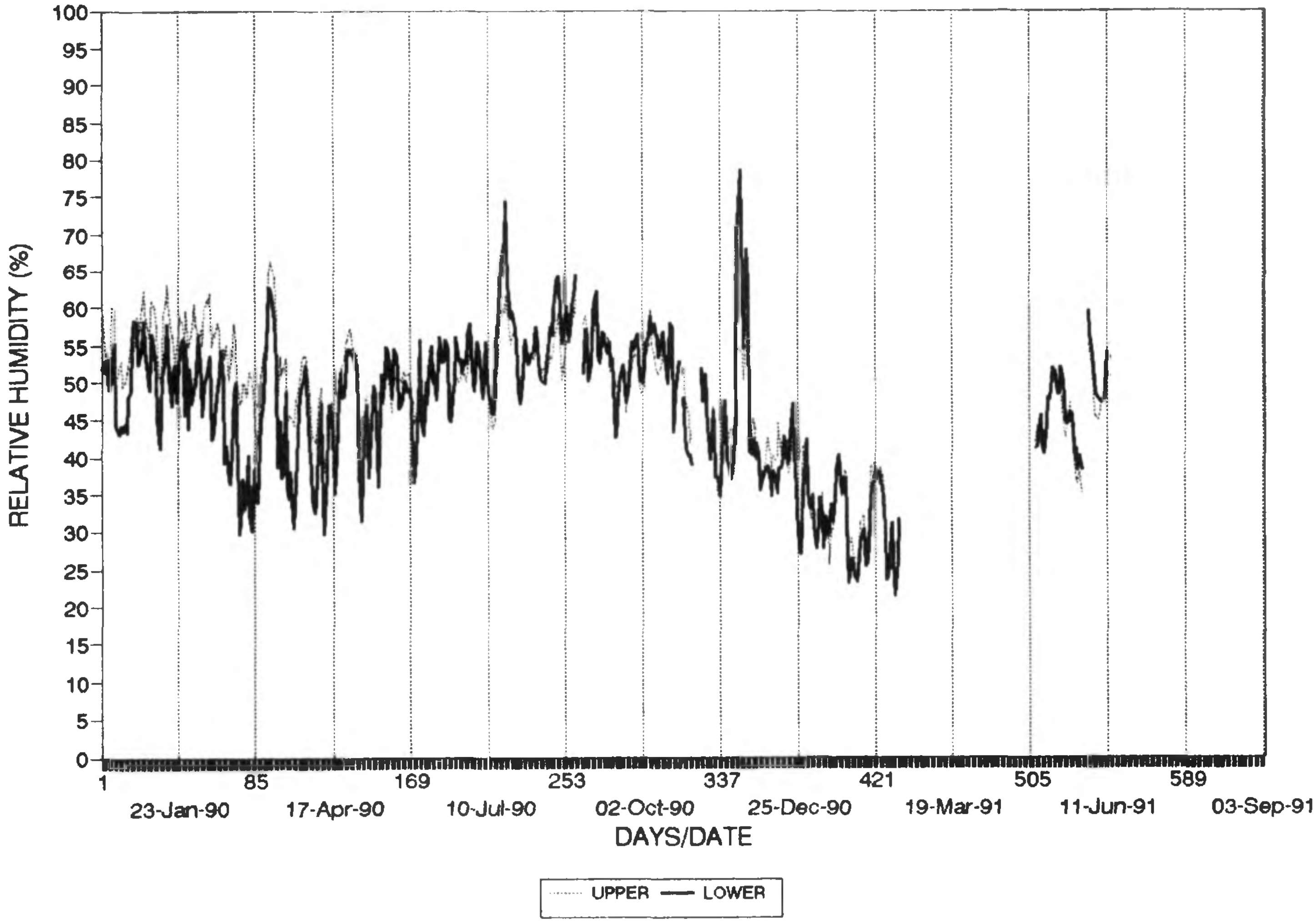
PANEL W5-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE



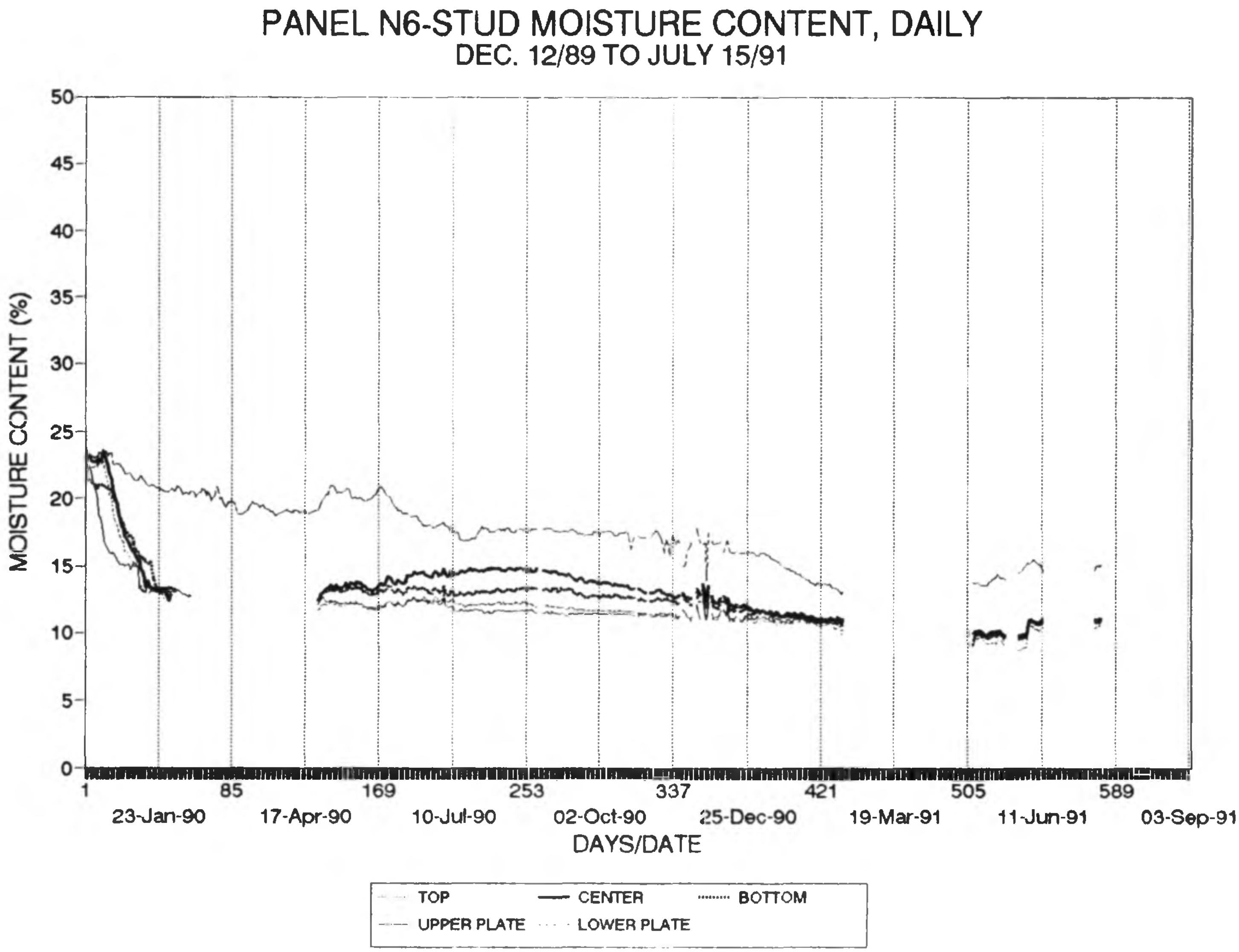
PANEL E6-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER


PANEL W6-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER

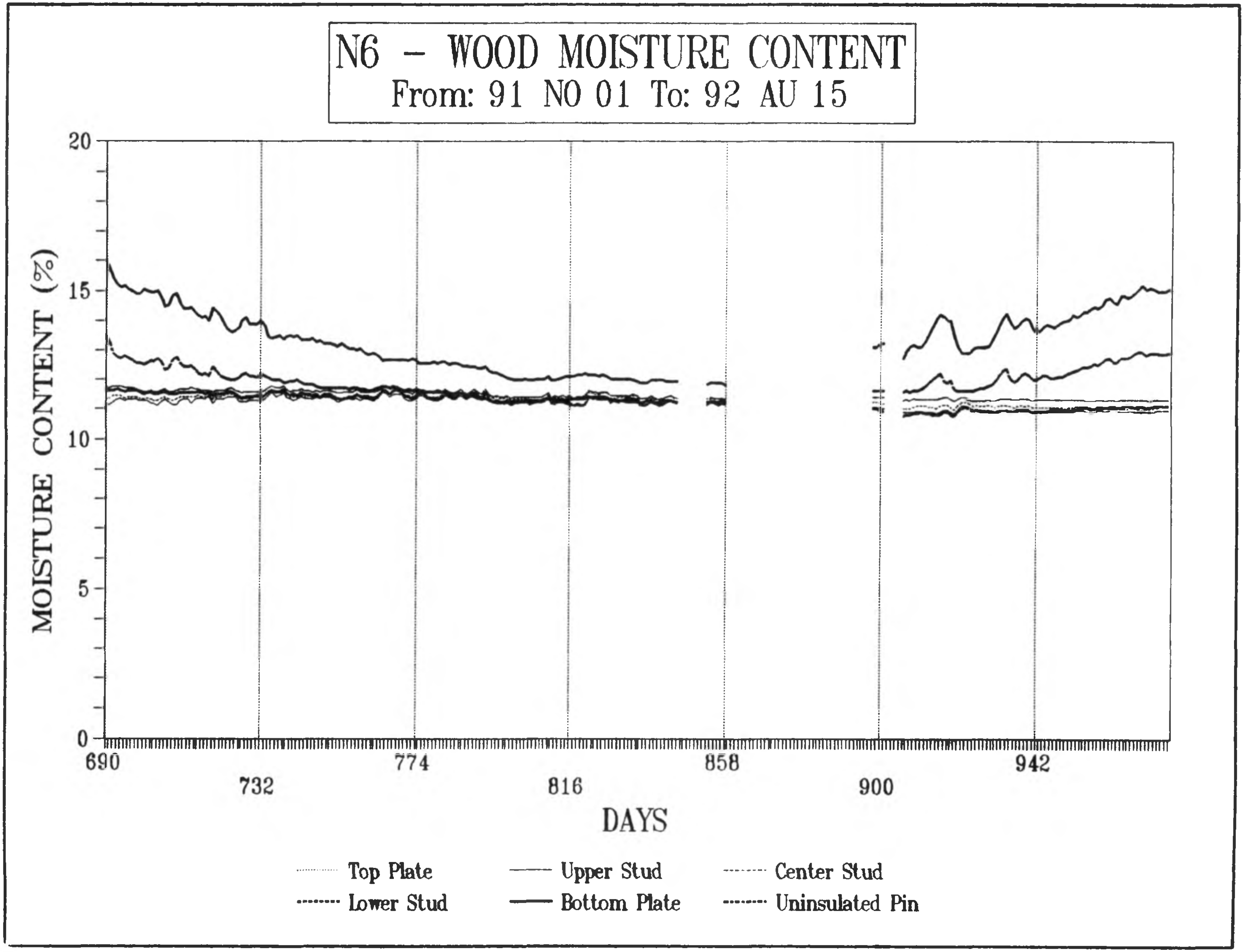
PANEL W5-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91



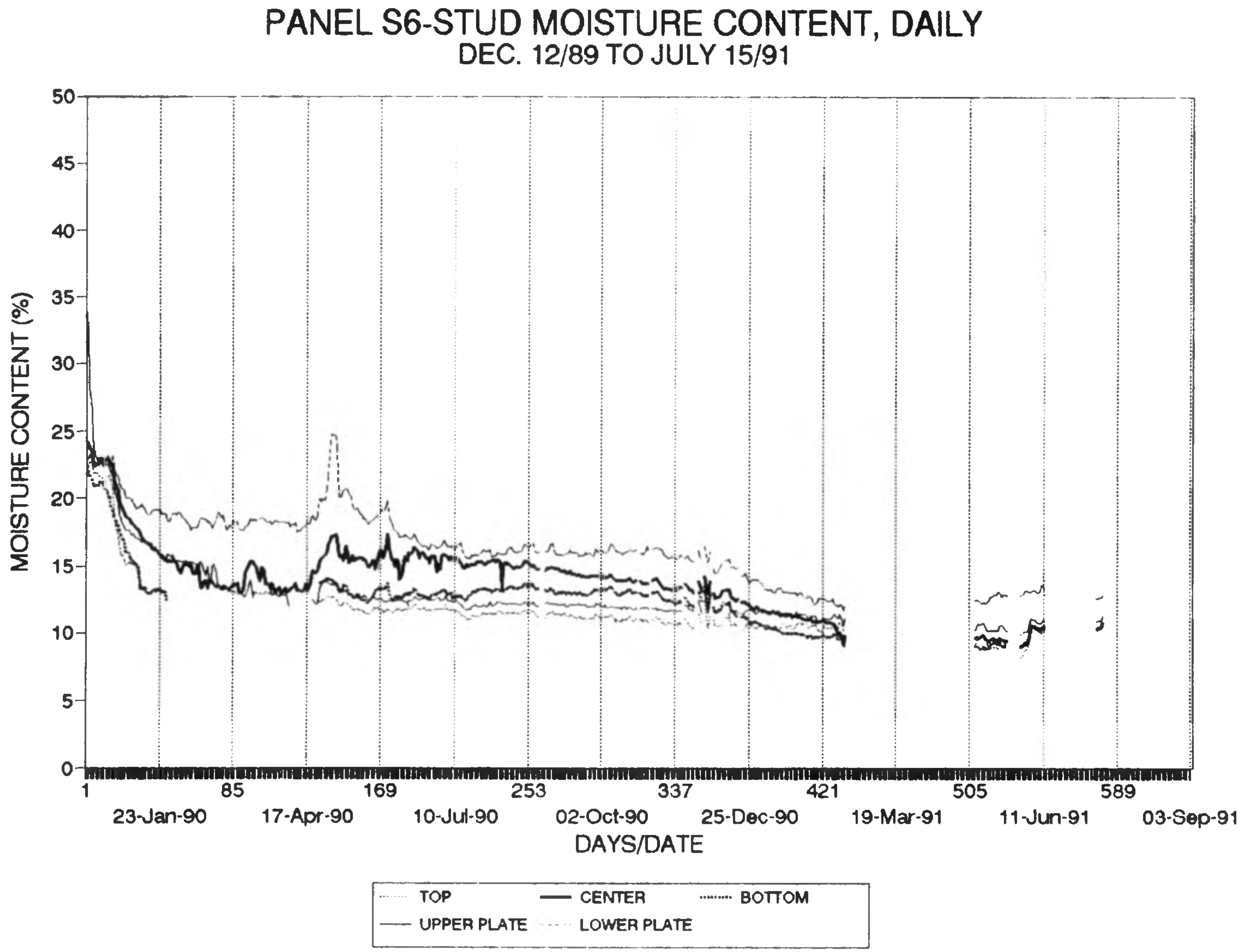
APPENDIX F: PANELS N6,S6



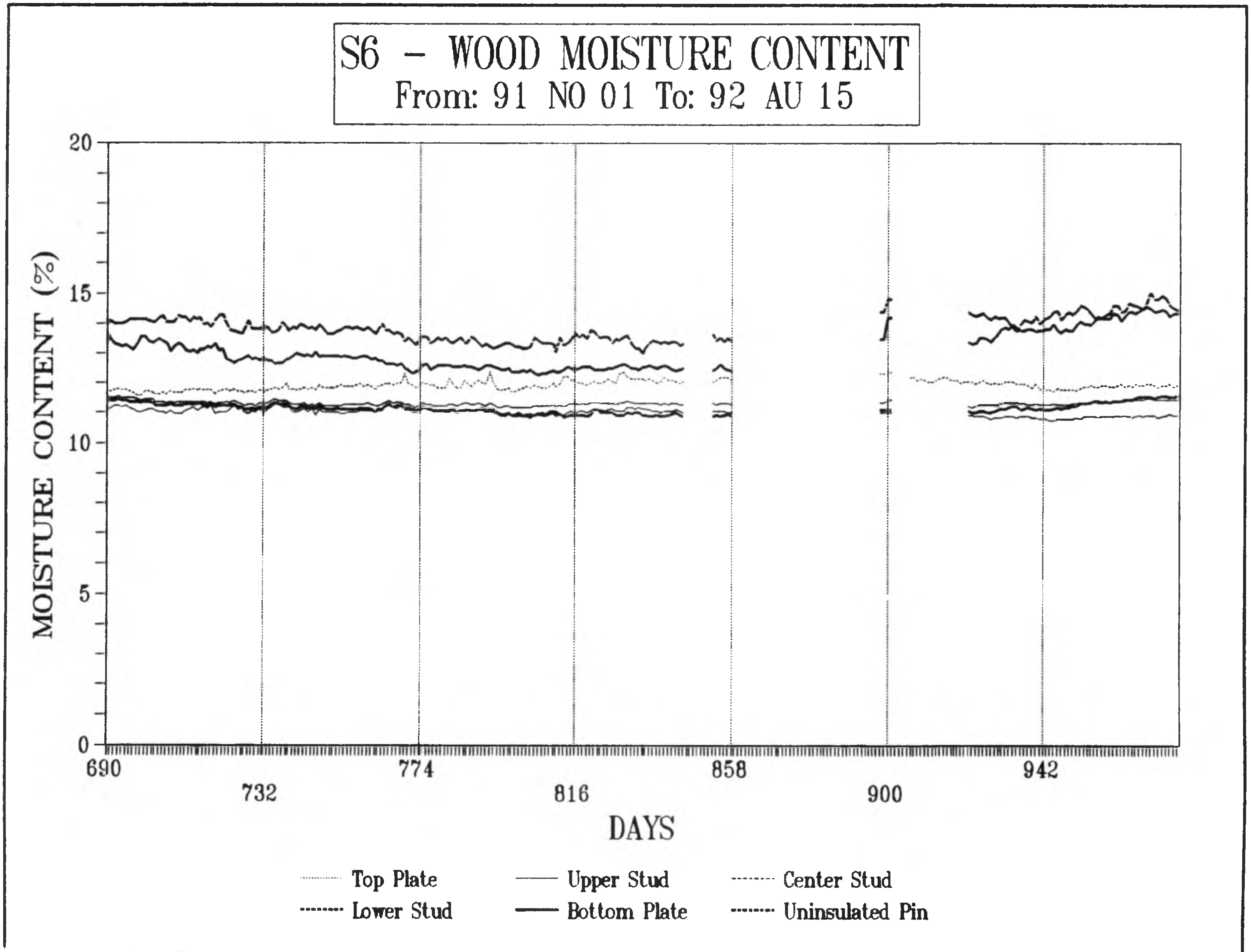
PANEL N6-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

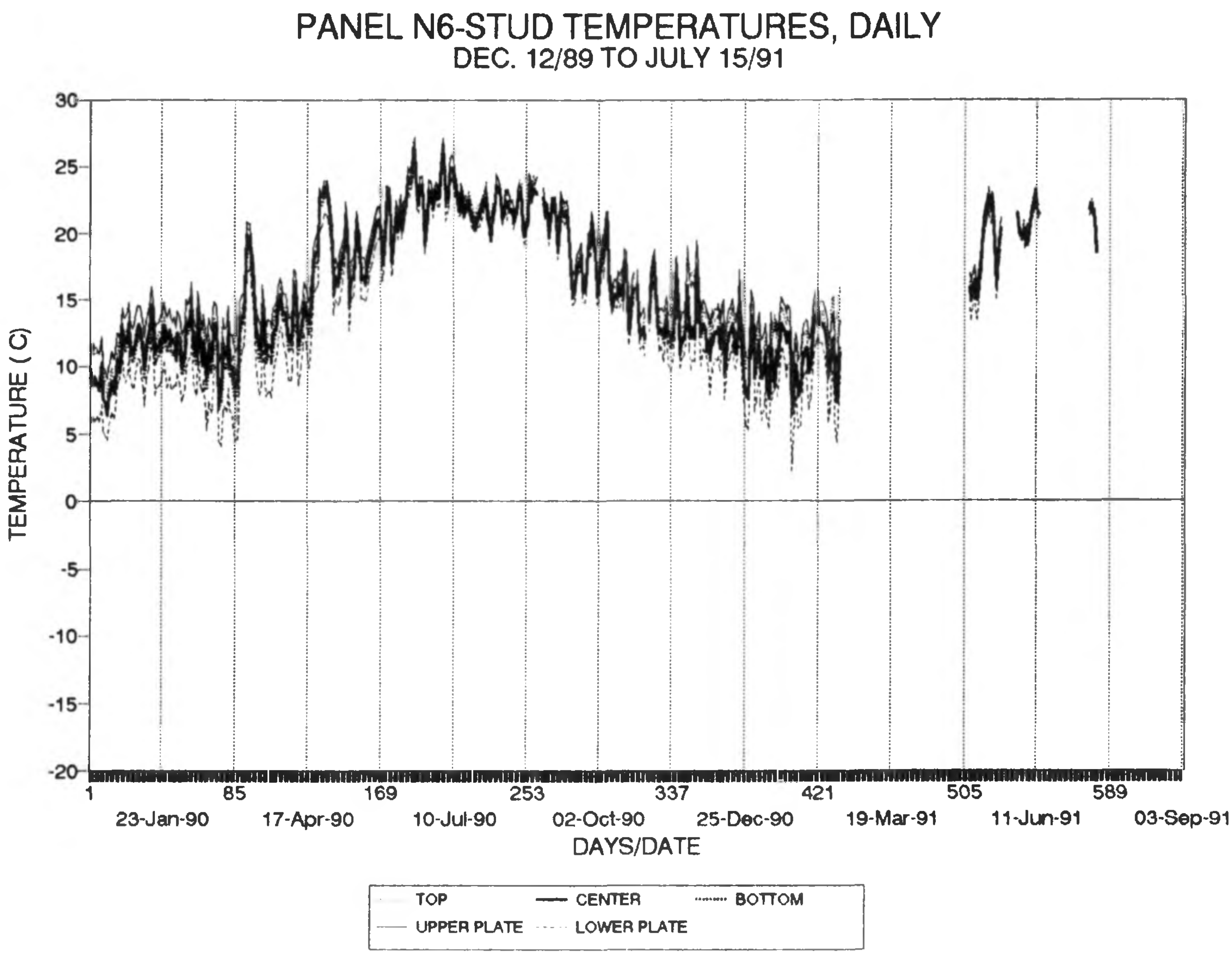


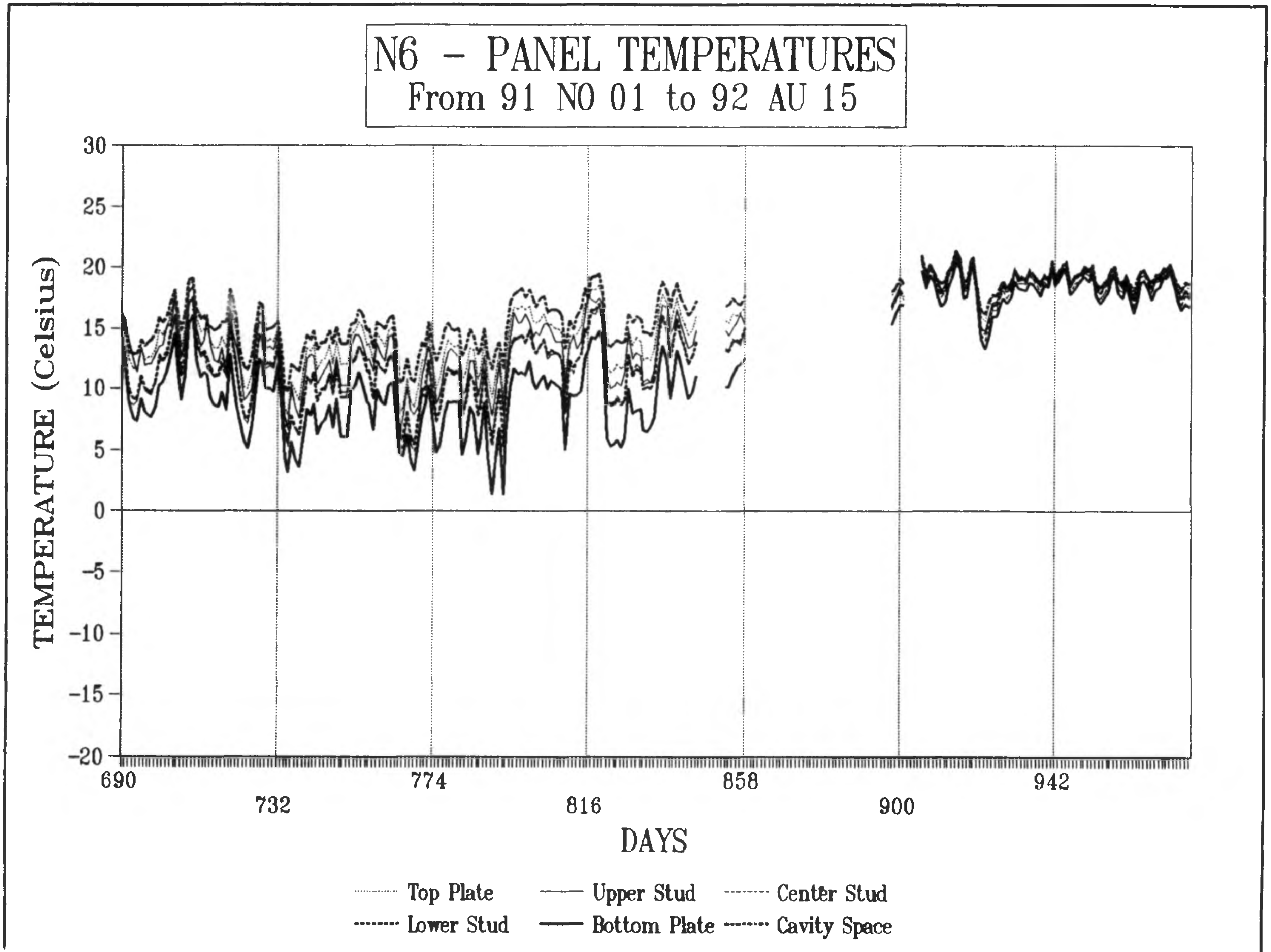
N6 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin



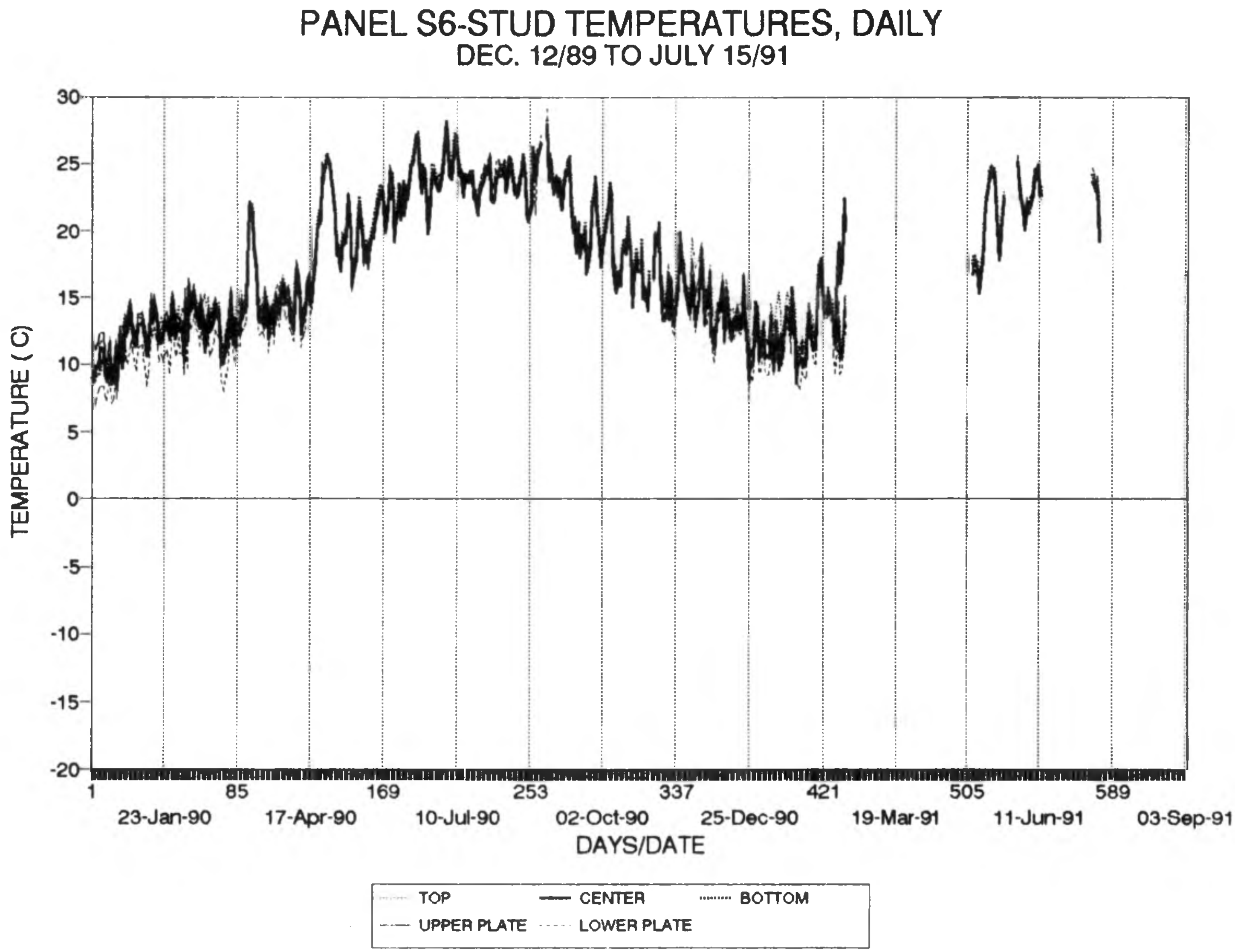
PANEL S6-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
0
5
10
15
20
25
30
35
40
45
50
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

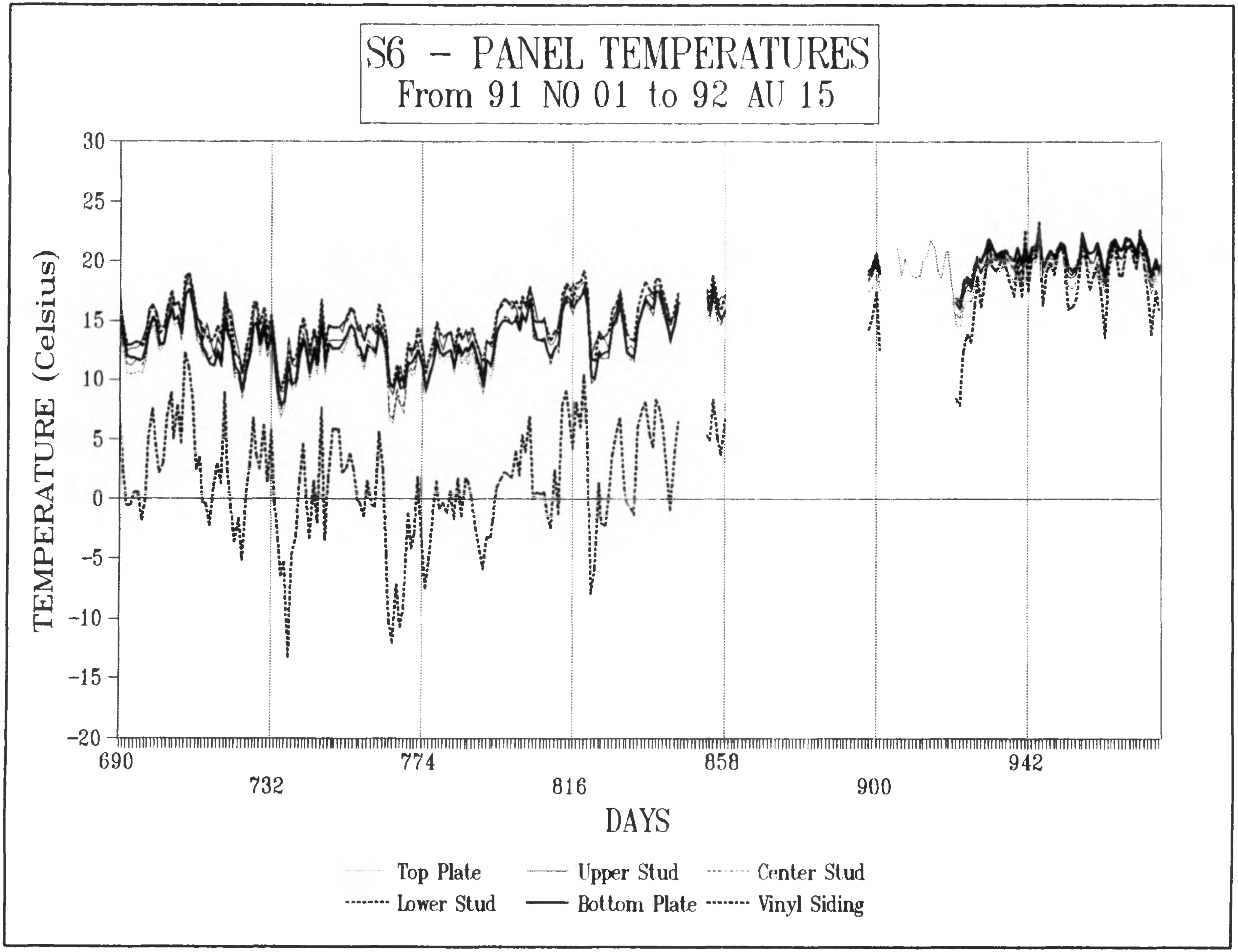

S6 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Uninsulated Pin


PANEL N6-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

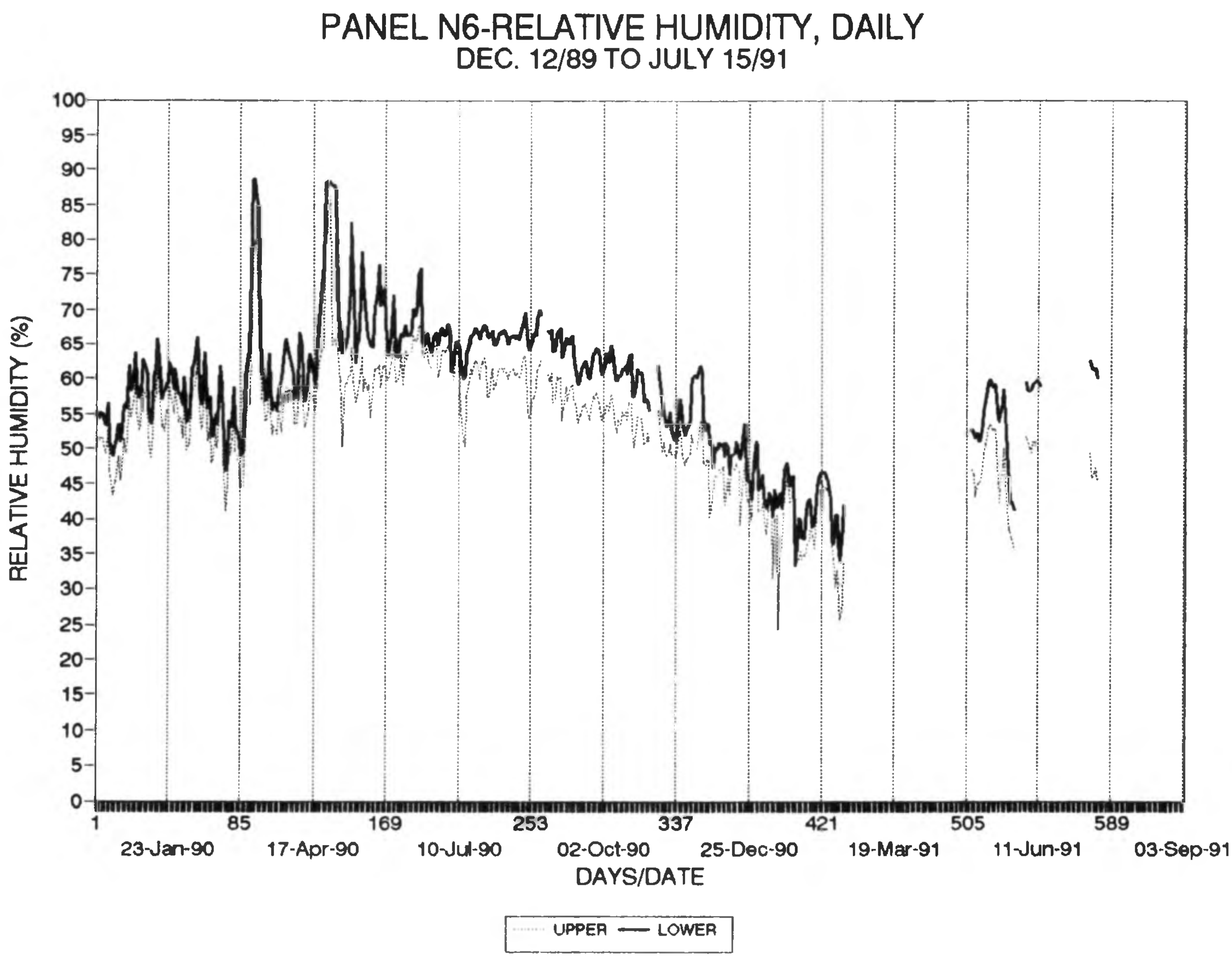


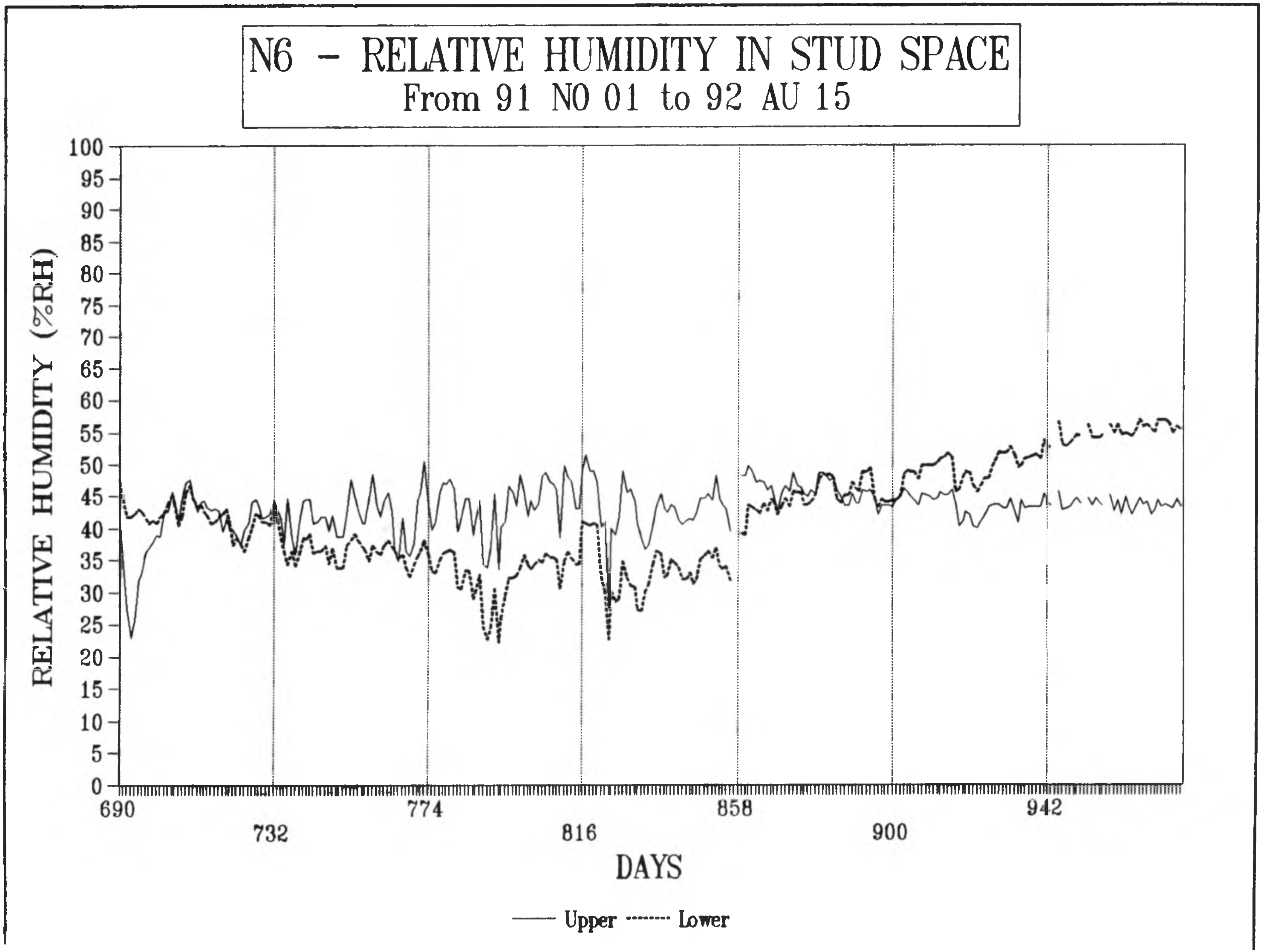
N6 - PANEL TEMPERATURES
From 91 NO 01 to 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Cavity Space


PANEL S6-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

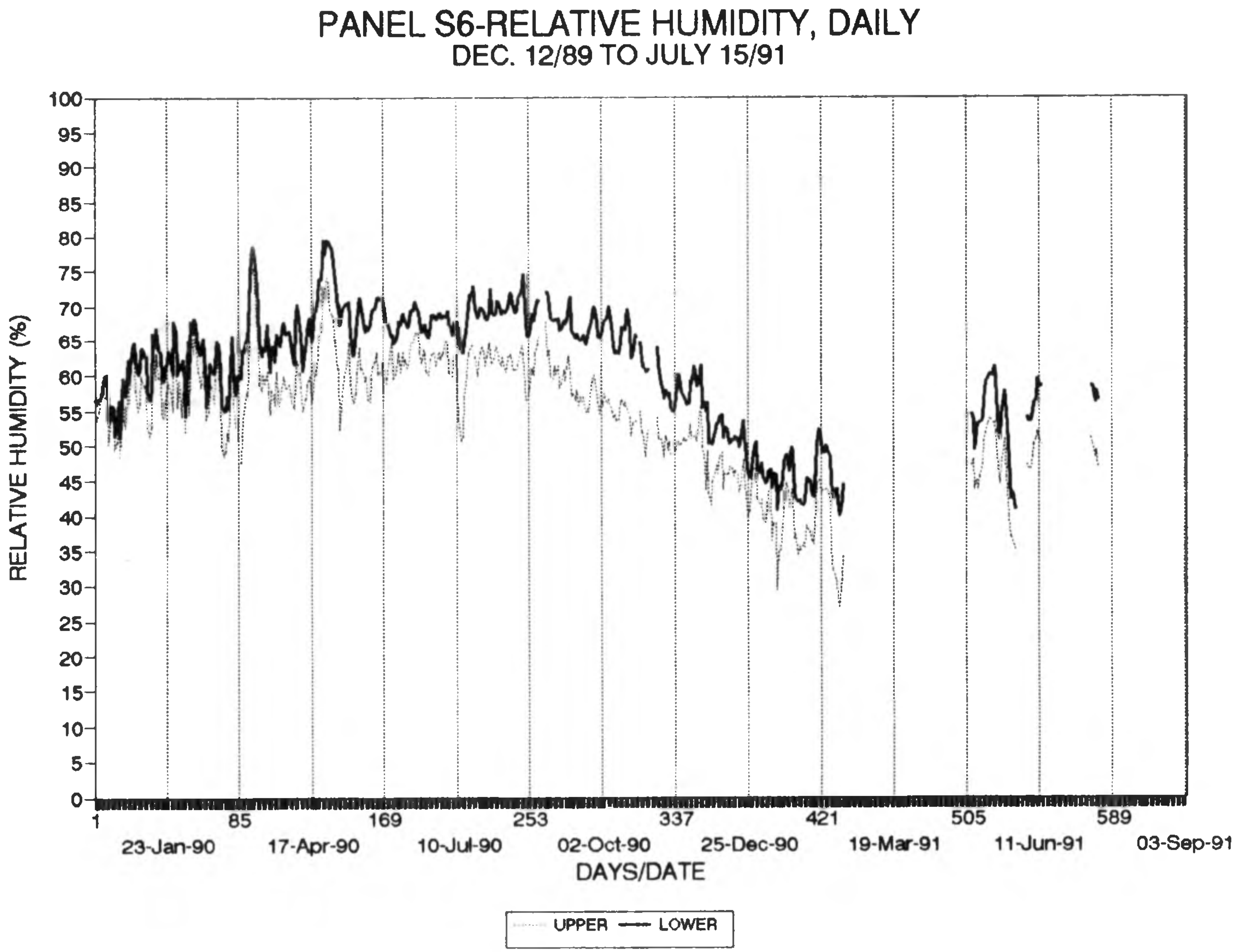


S6 - PANEL TEMPERATURES
From 91 NO 01 to 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Vinyl Siding

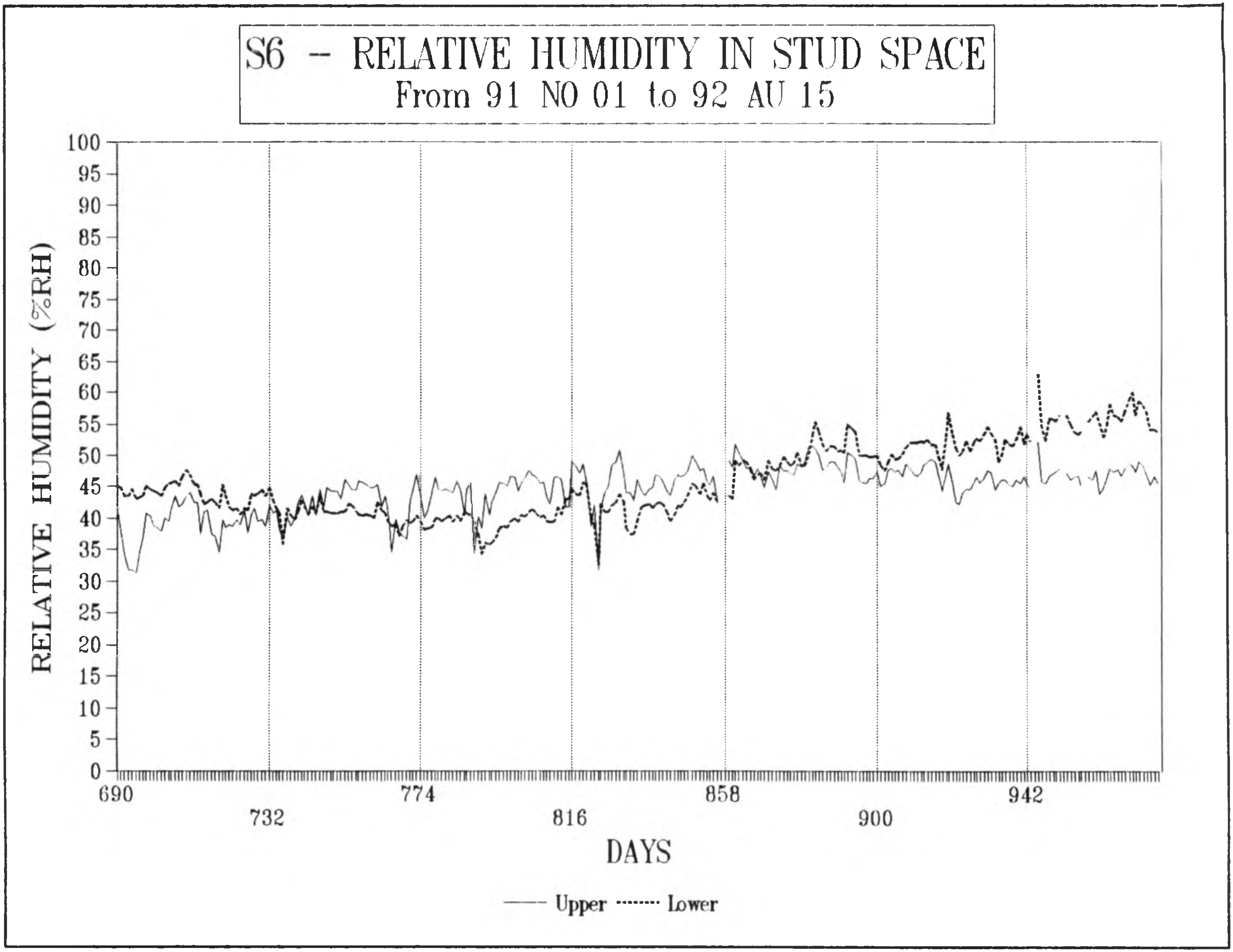

PANEL N6-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER



N6 - RELATIVE HUMIDITY IN STUD SPACE
From 91 NO 01 to 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower



PANEL S6-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER

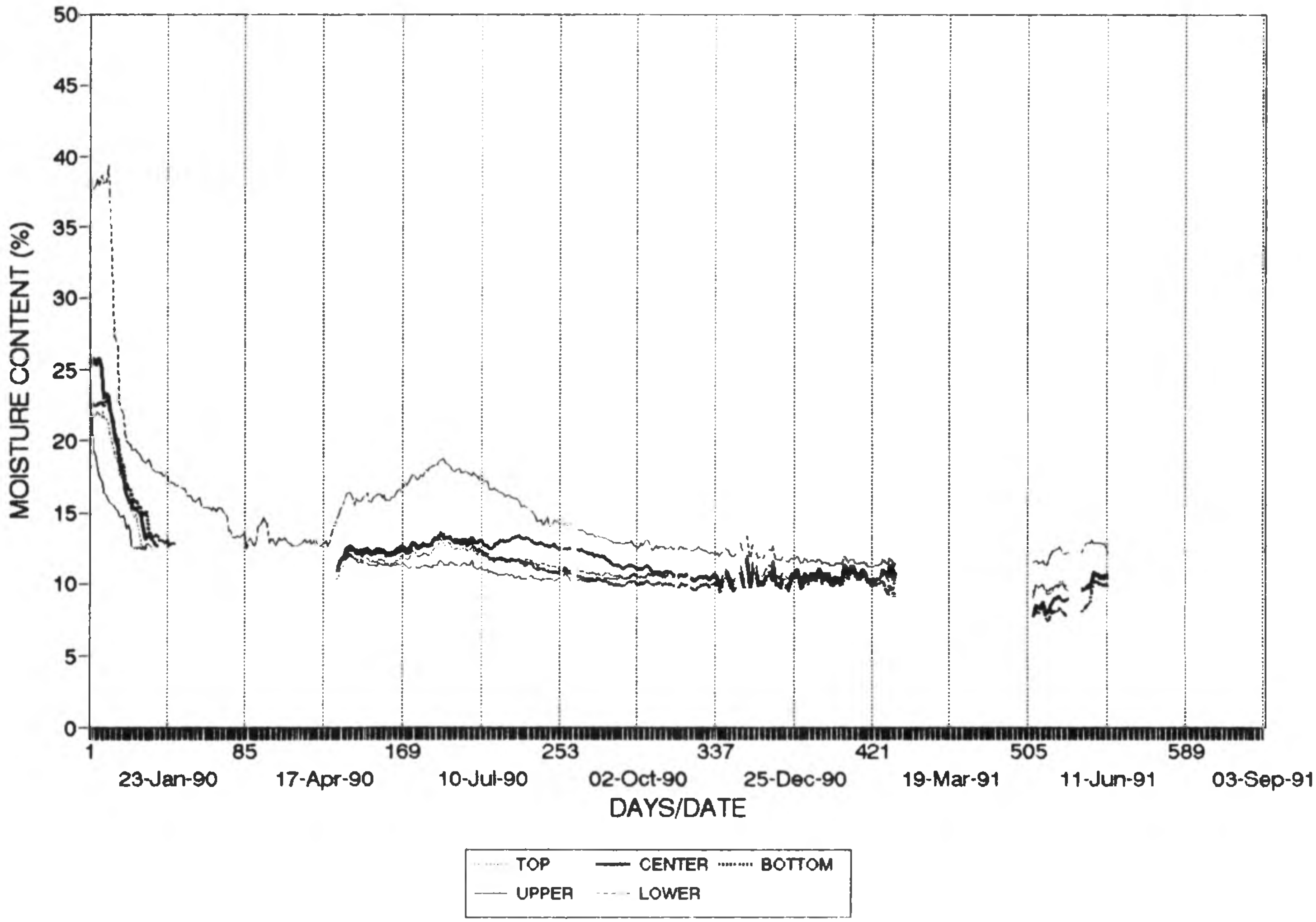


S6 – RELATIVE HUMIDITY IN STUD SPACE
From 91 NO 01 to 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower

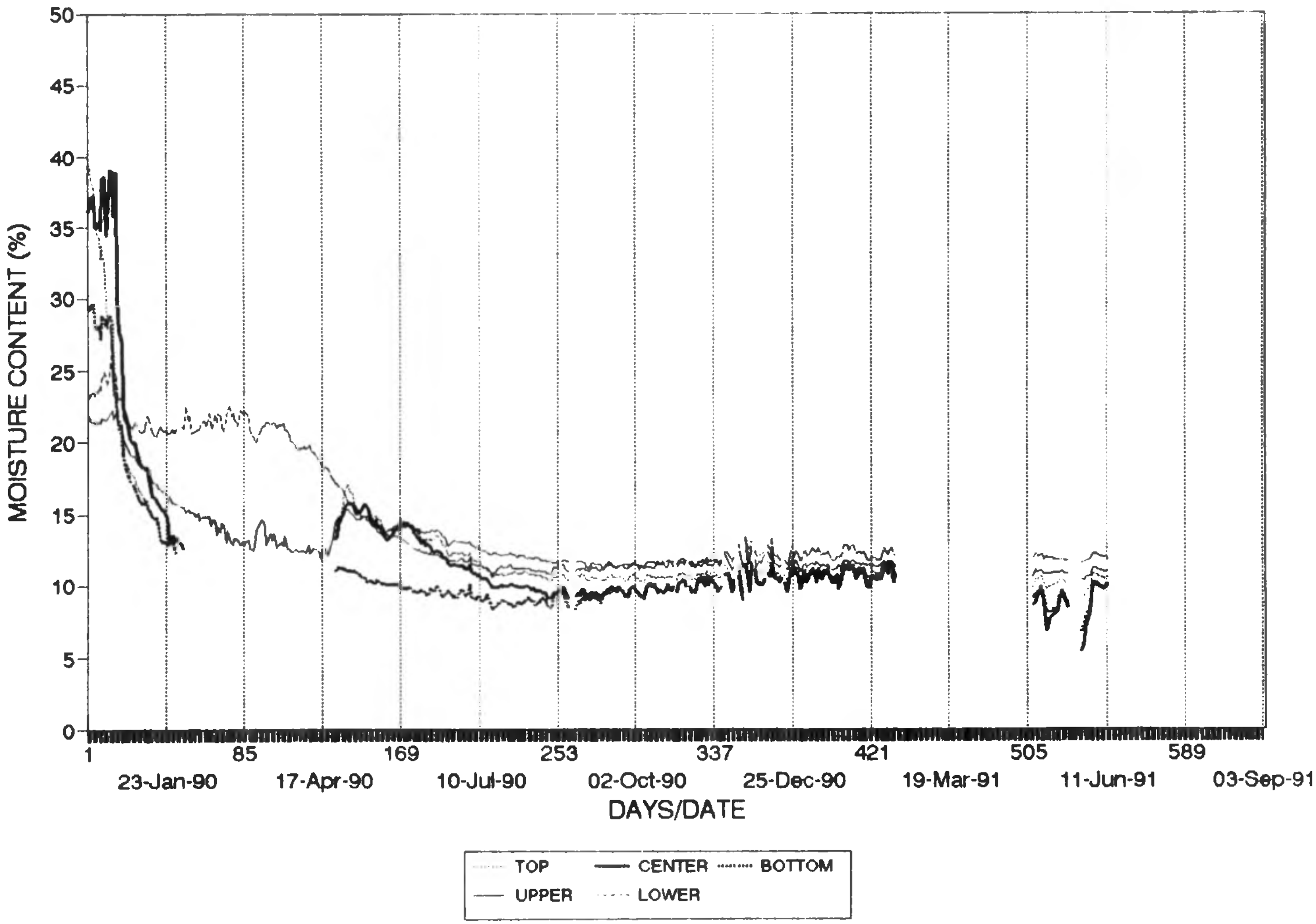
APPENDIX G: PANELS N2,S2

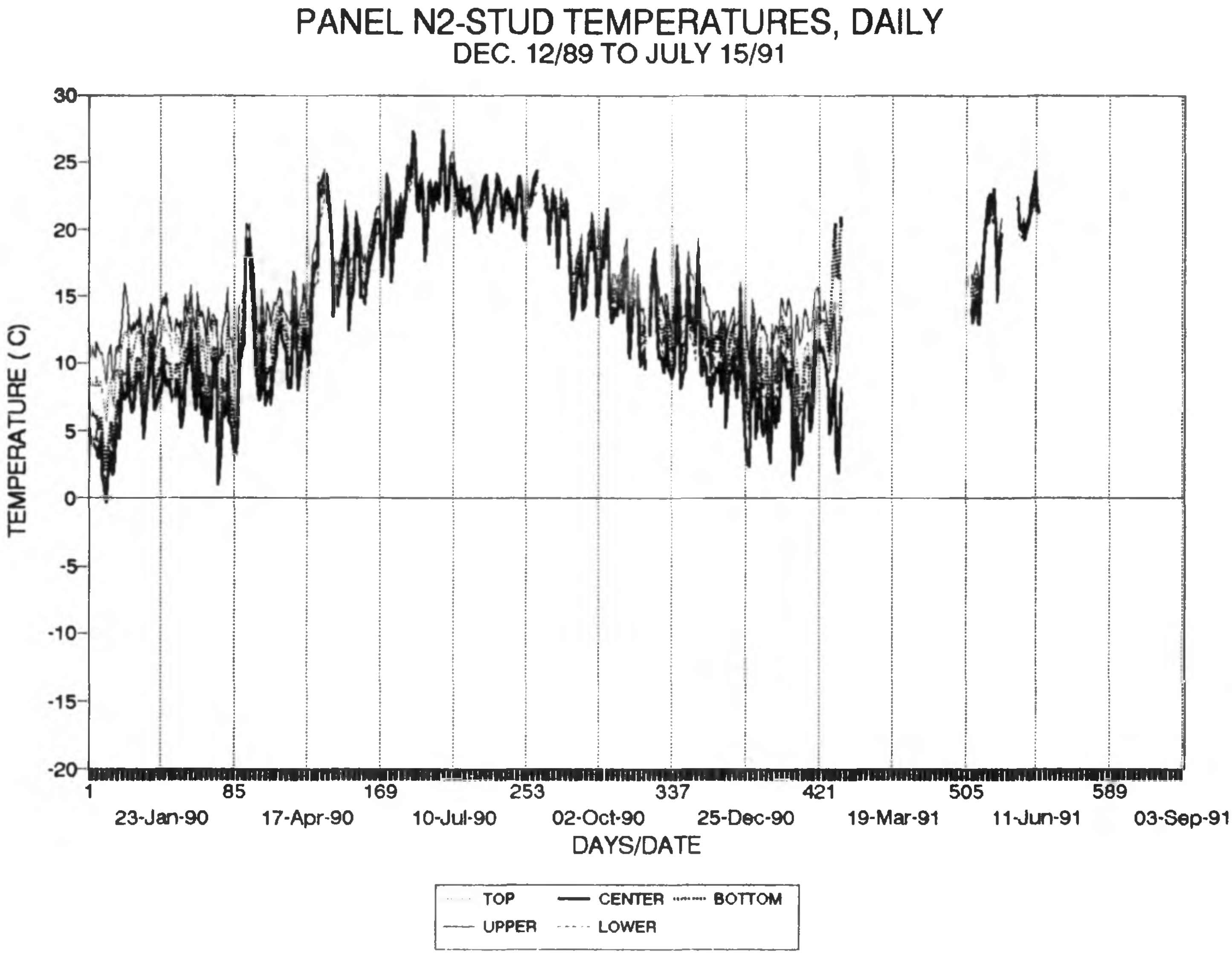
PANEL N2-STUD MOISTURE CONTENT, DAILY

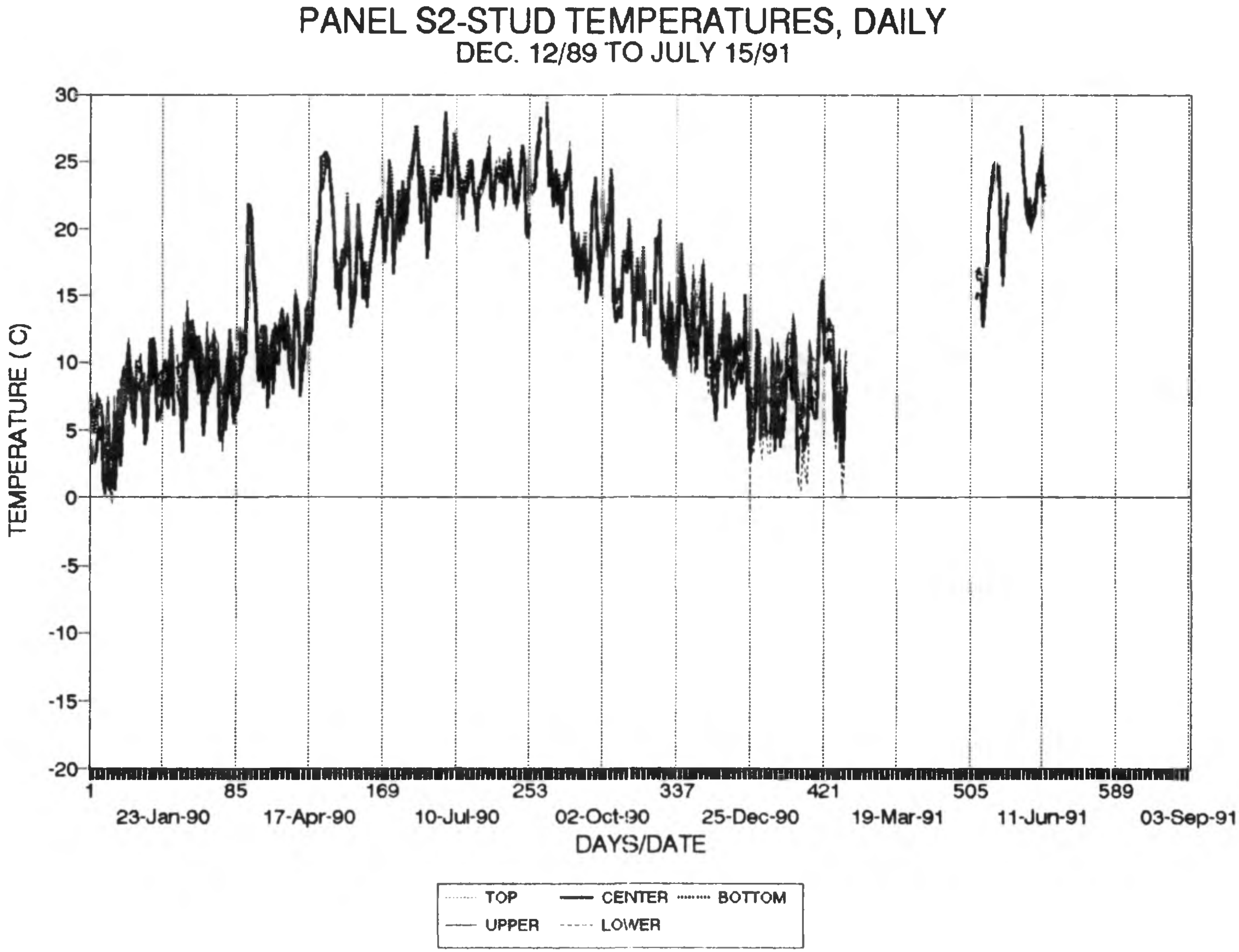
DEC. 12/89 TO JULY 15/91



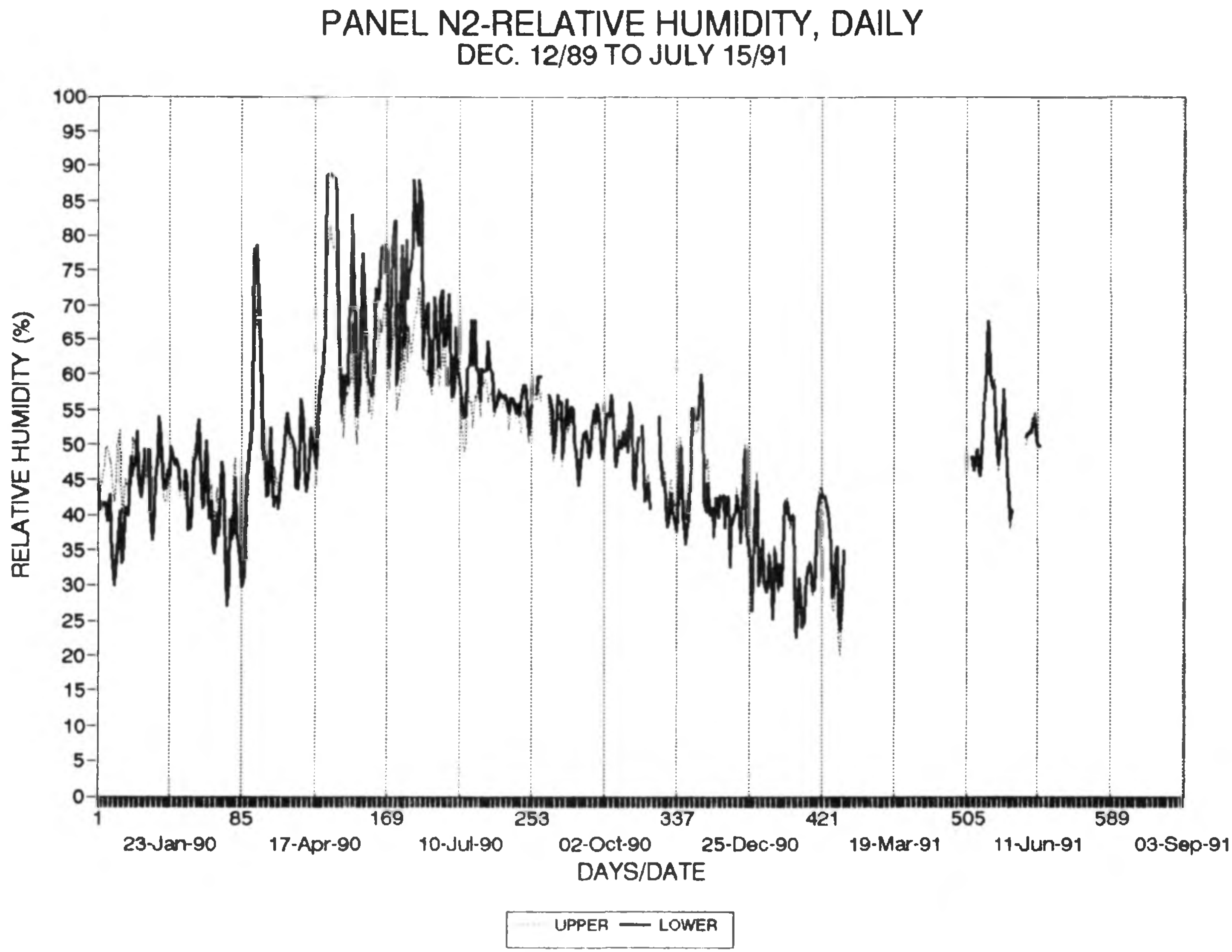
PANEL S2-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91

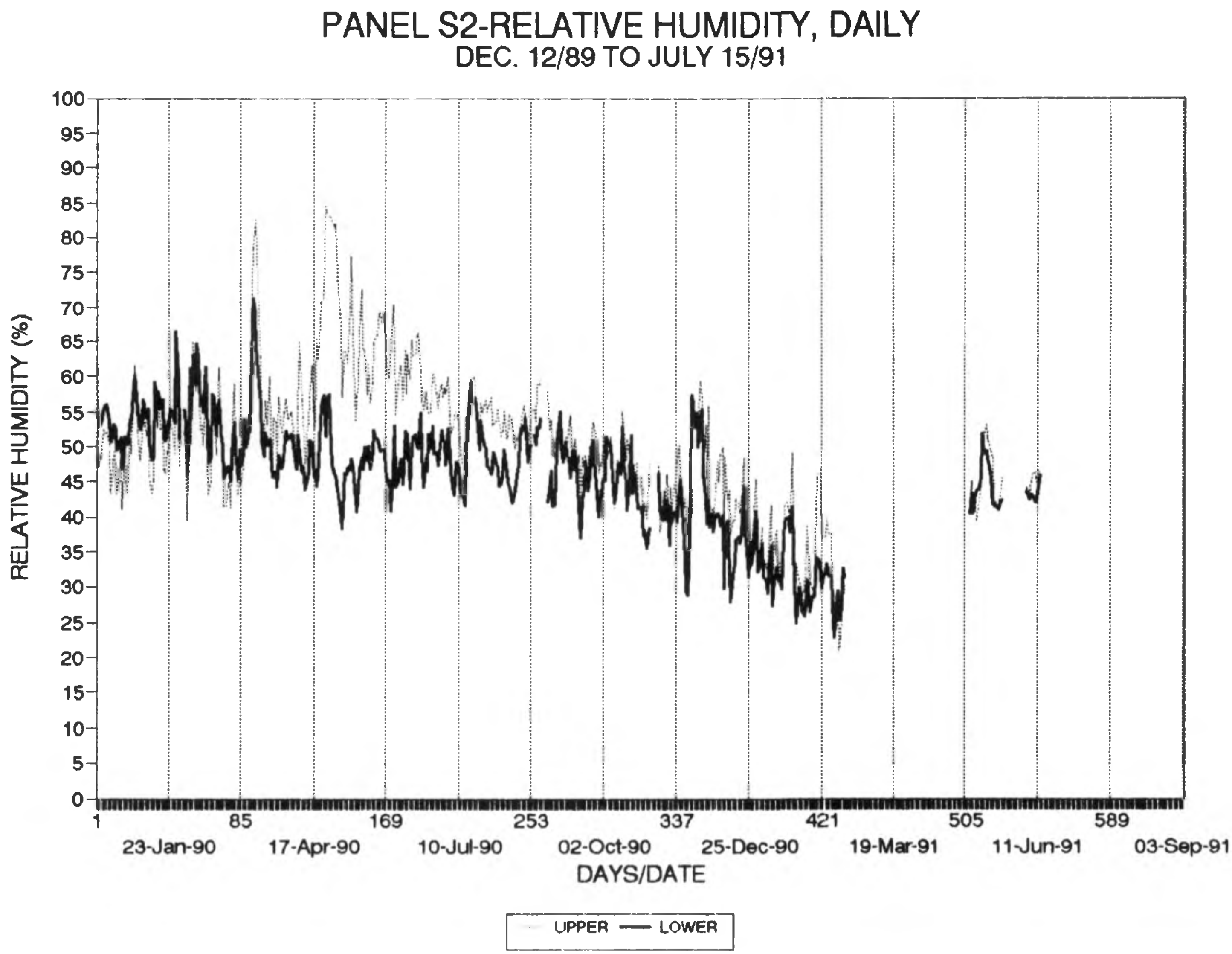



PANEL N2-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER
LOWER

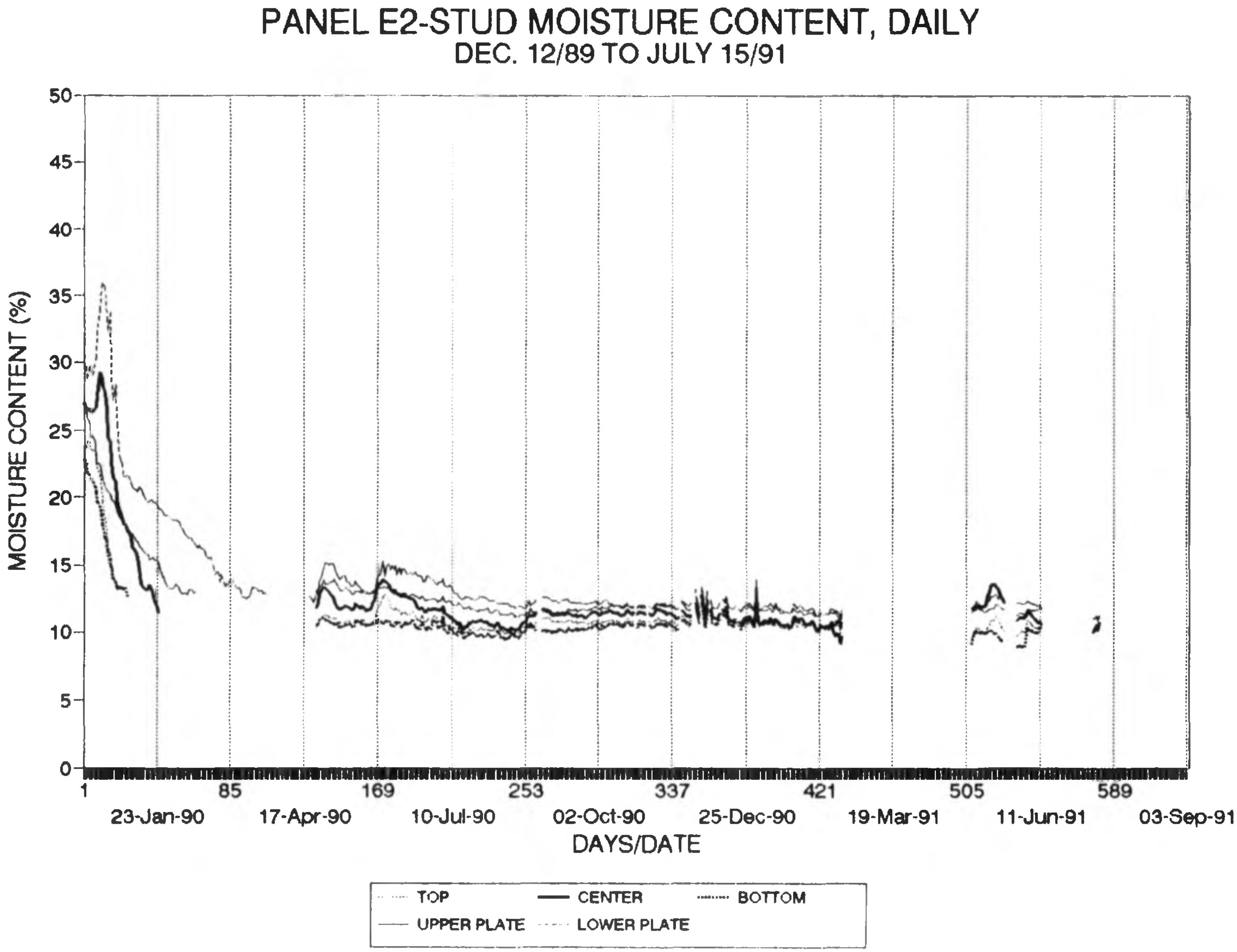


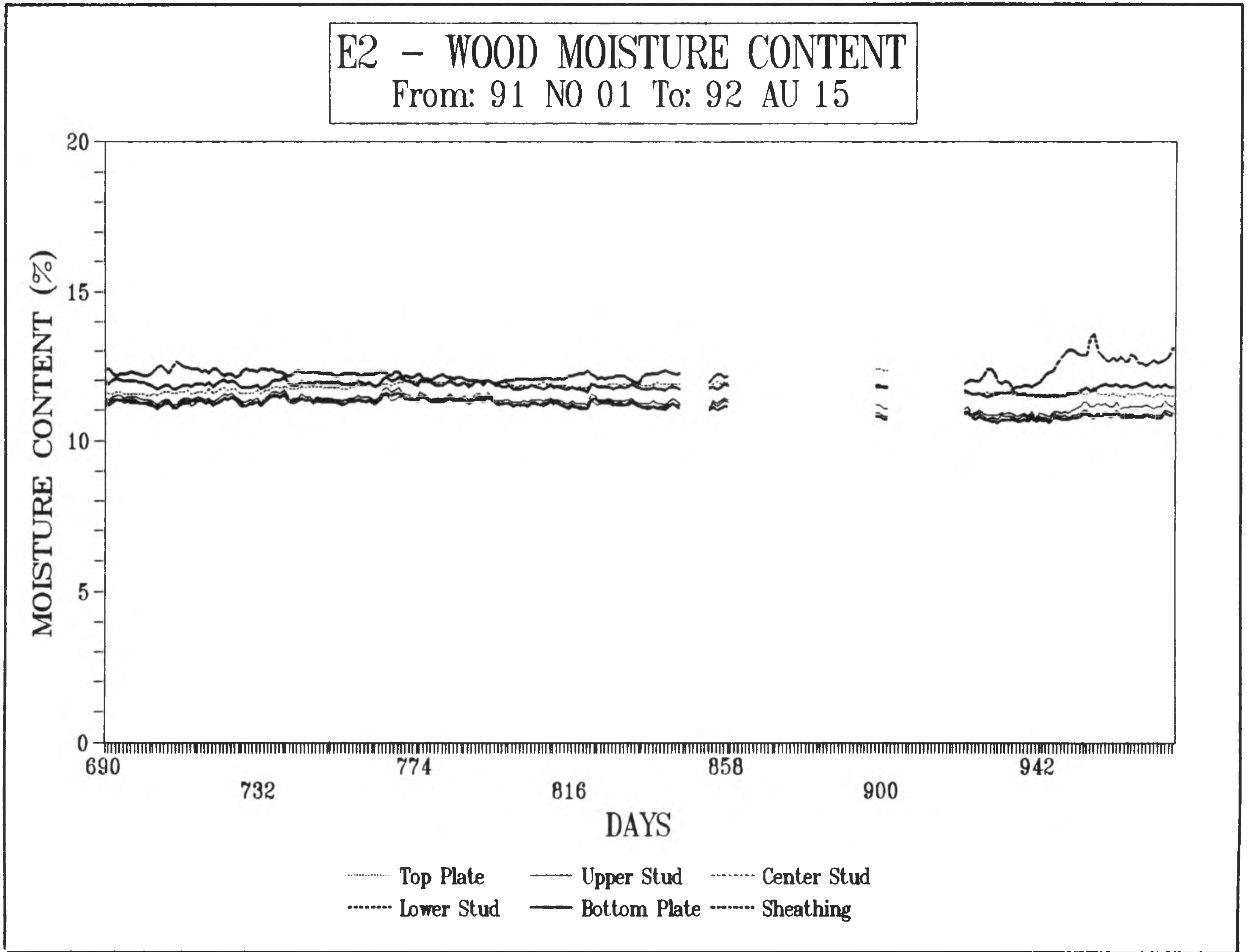
PANEL S2-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER
LOWER

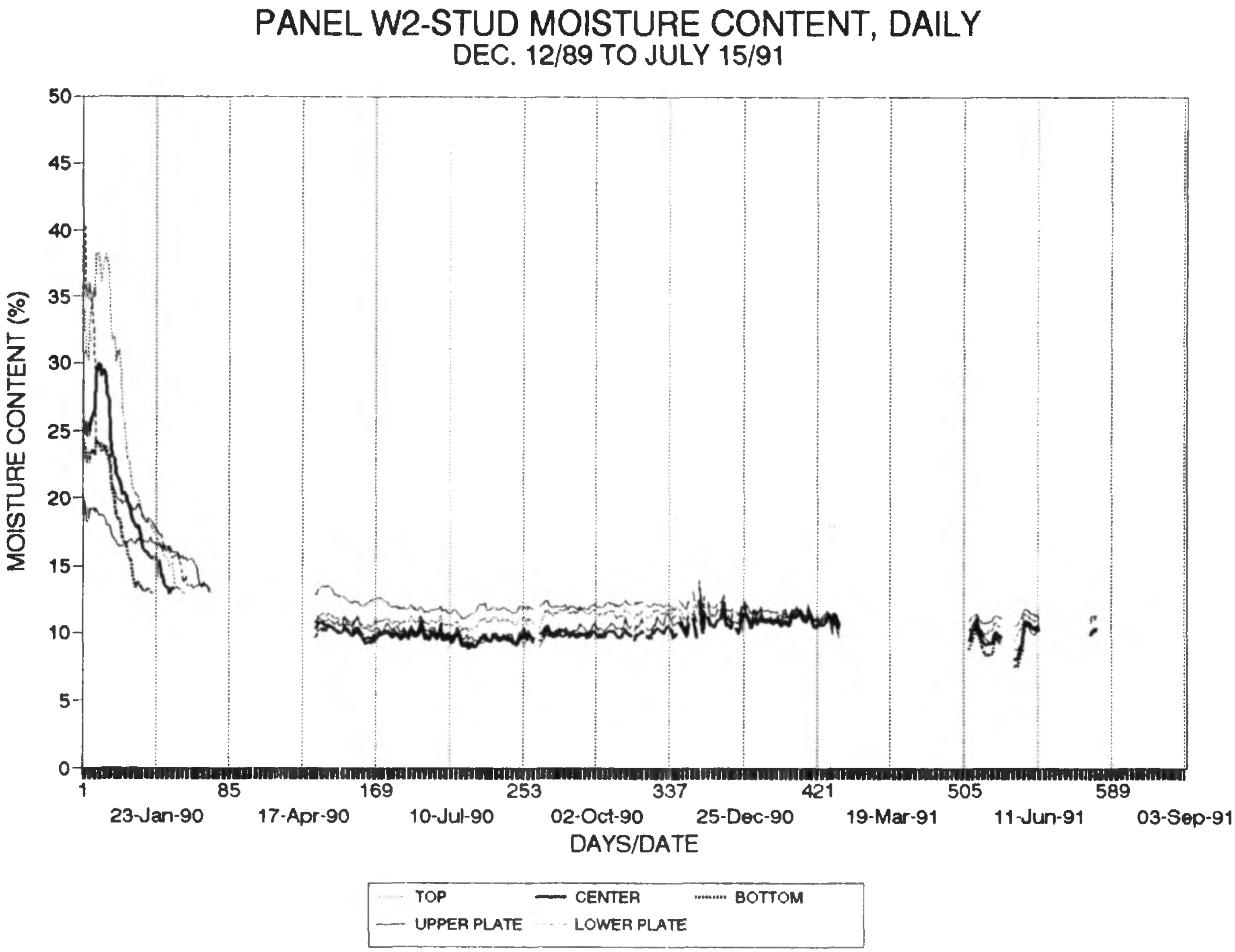

PANEL N2-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER

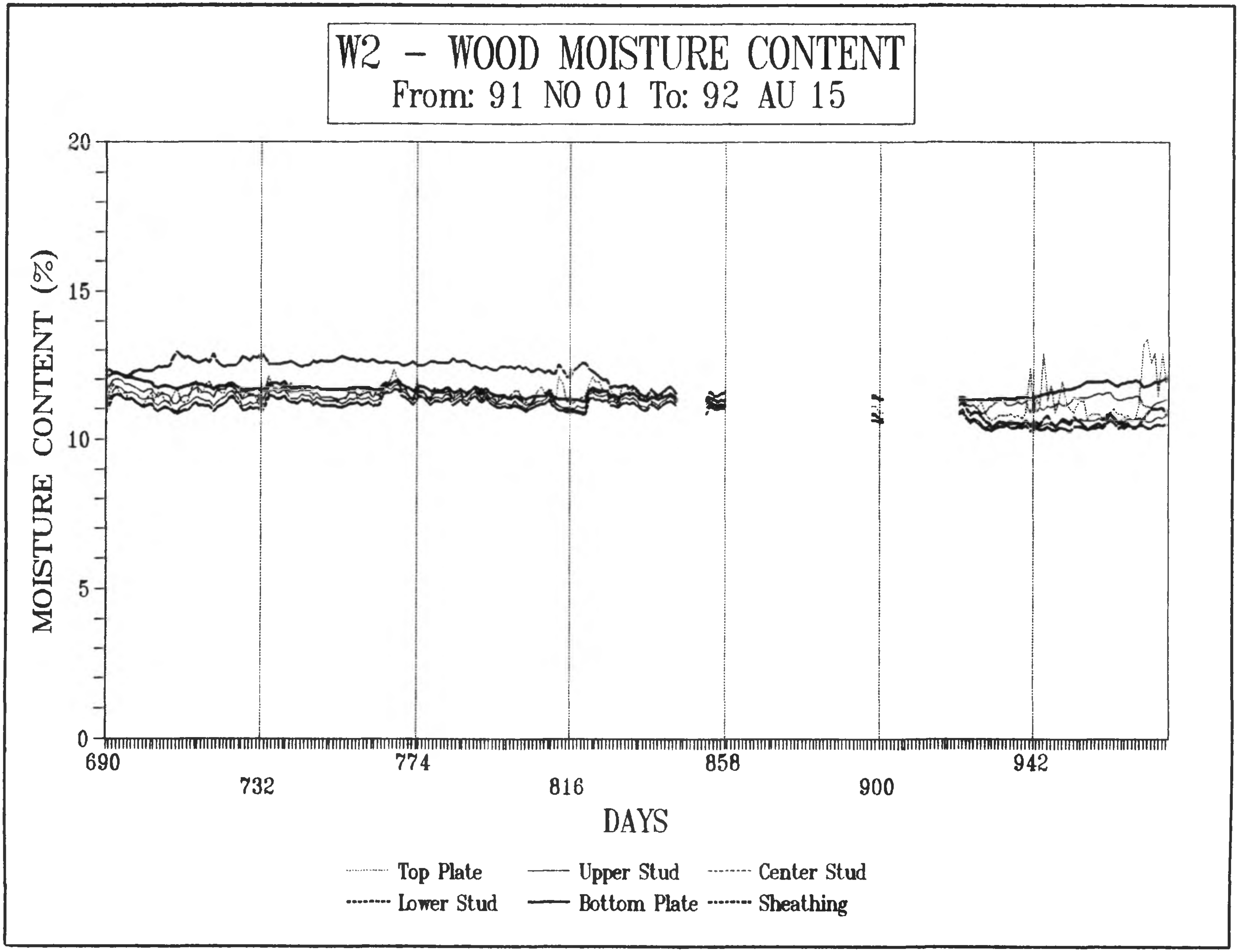

PANEL S2-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER

APPENDIX H: PANELS E2,W2

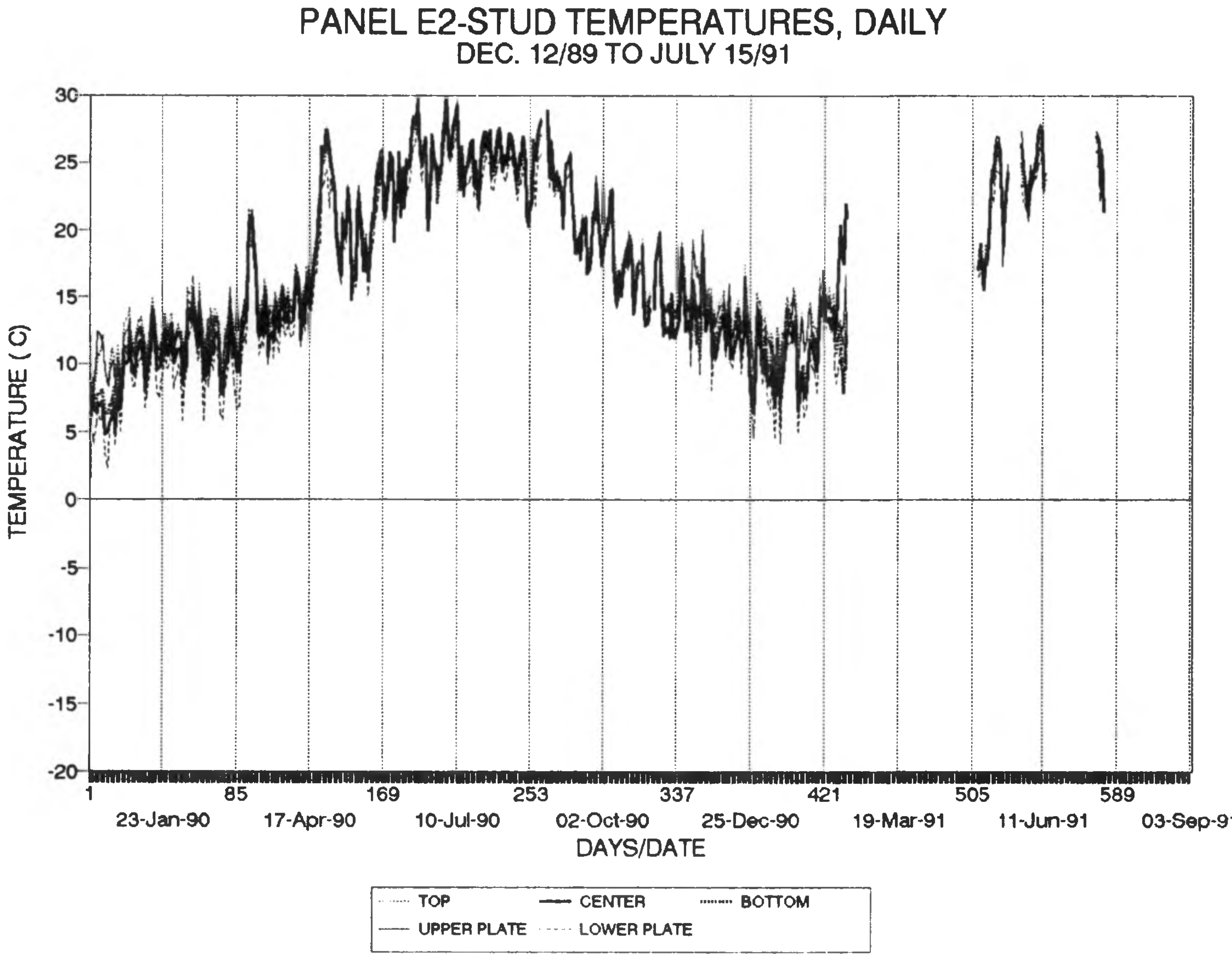

PANEL E2-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE


E2 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Sheathing

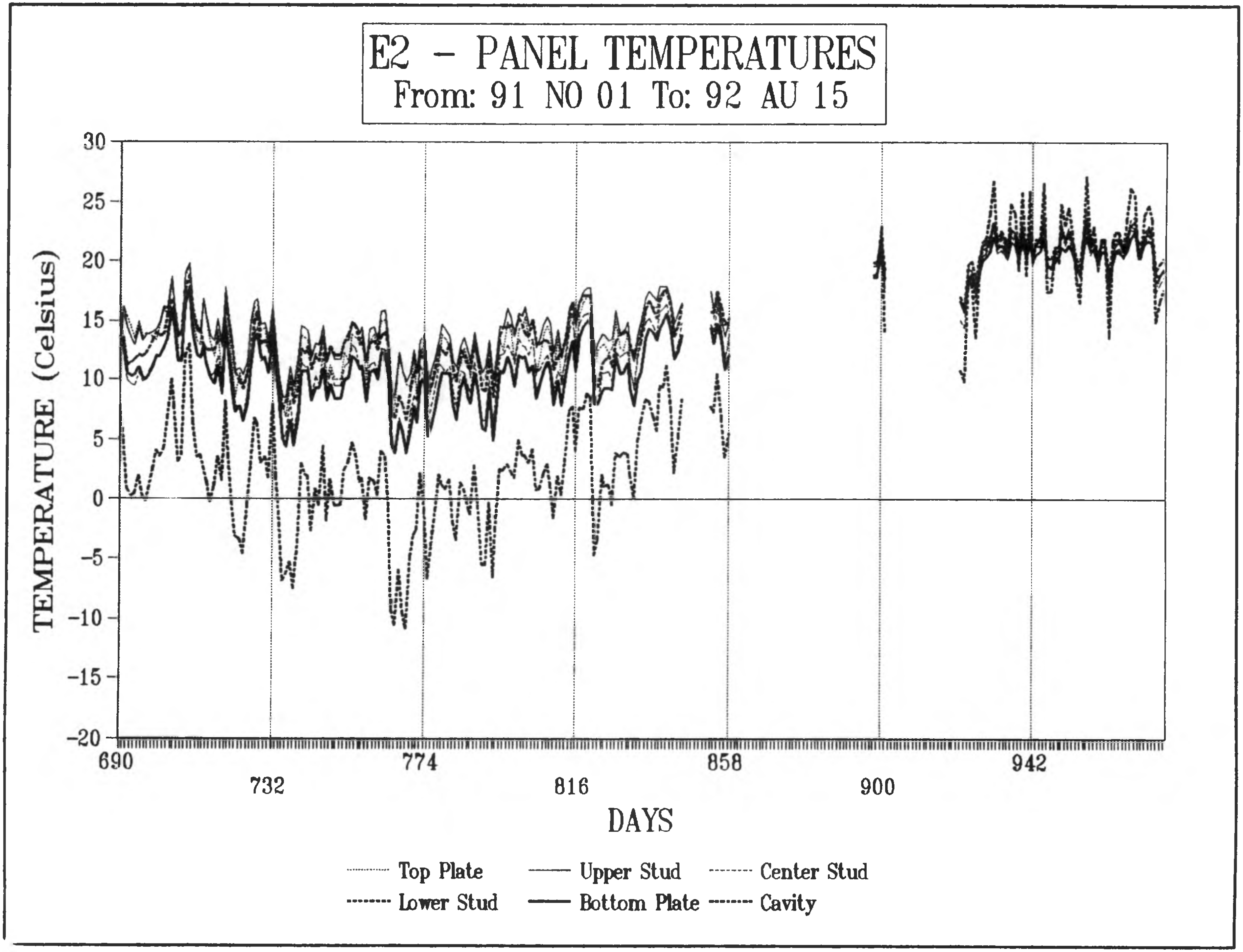

PANEL W2-STUD MOISTURE CONTENT, DAILY
DEC. 12/89 TO JULY 15/91
MOISTURE CONTENT (%)
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE



W2 - WOOD MOISTURE CONTENT
From: 91 NO 01 To: 92 AU 15
MOISTURE CONTENT (%)
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Sheathing



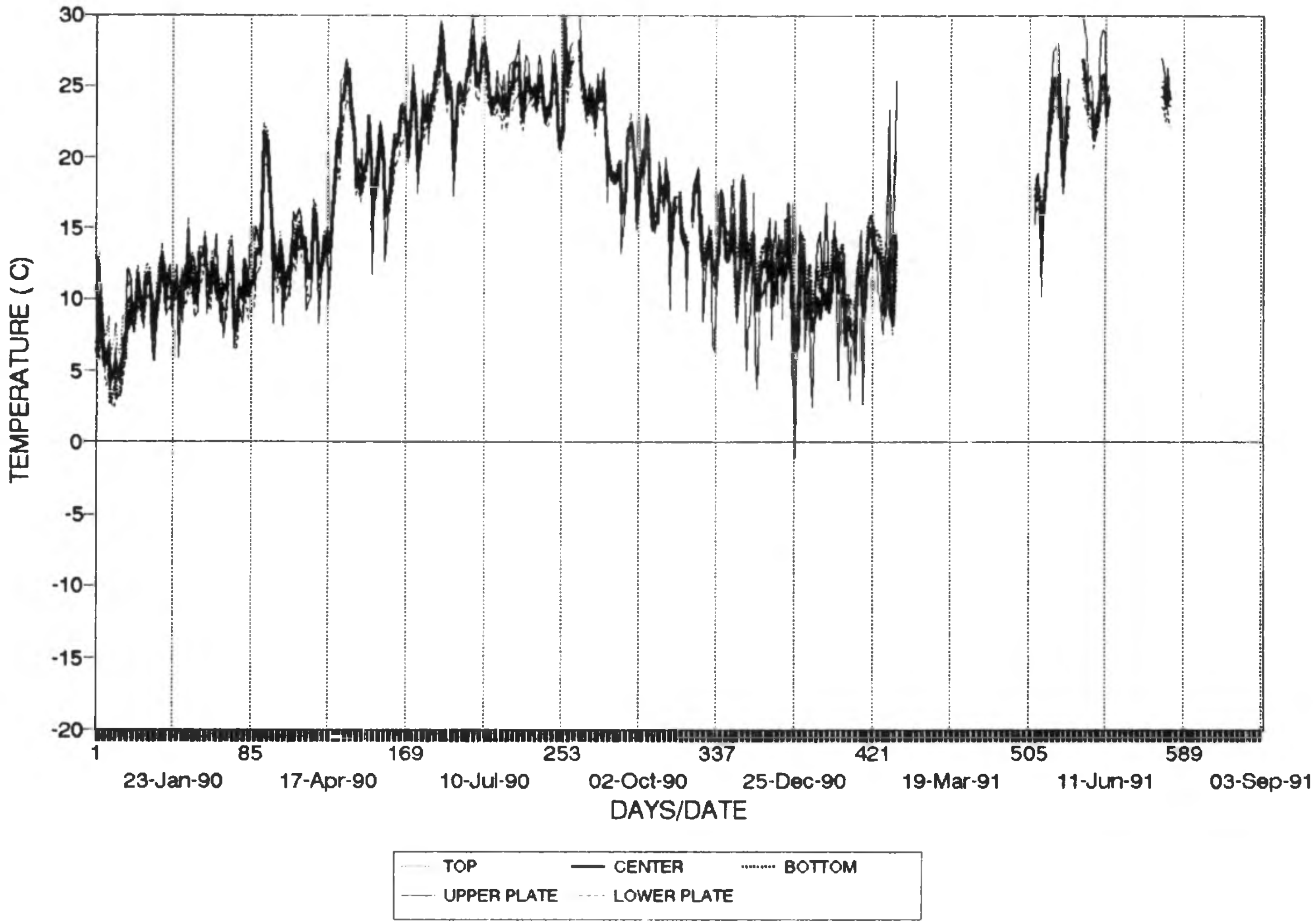
PANEL E2-STUD TEMPERATURES, DAILY
DEC. 12/89 TO JULY 15/91
TEMPERATURE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
TOP
CENTER
BOTTOM
UPPER PLATE
LOWER PLATE

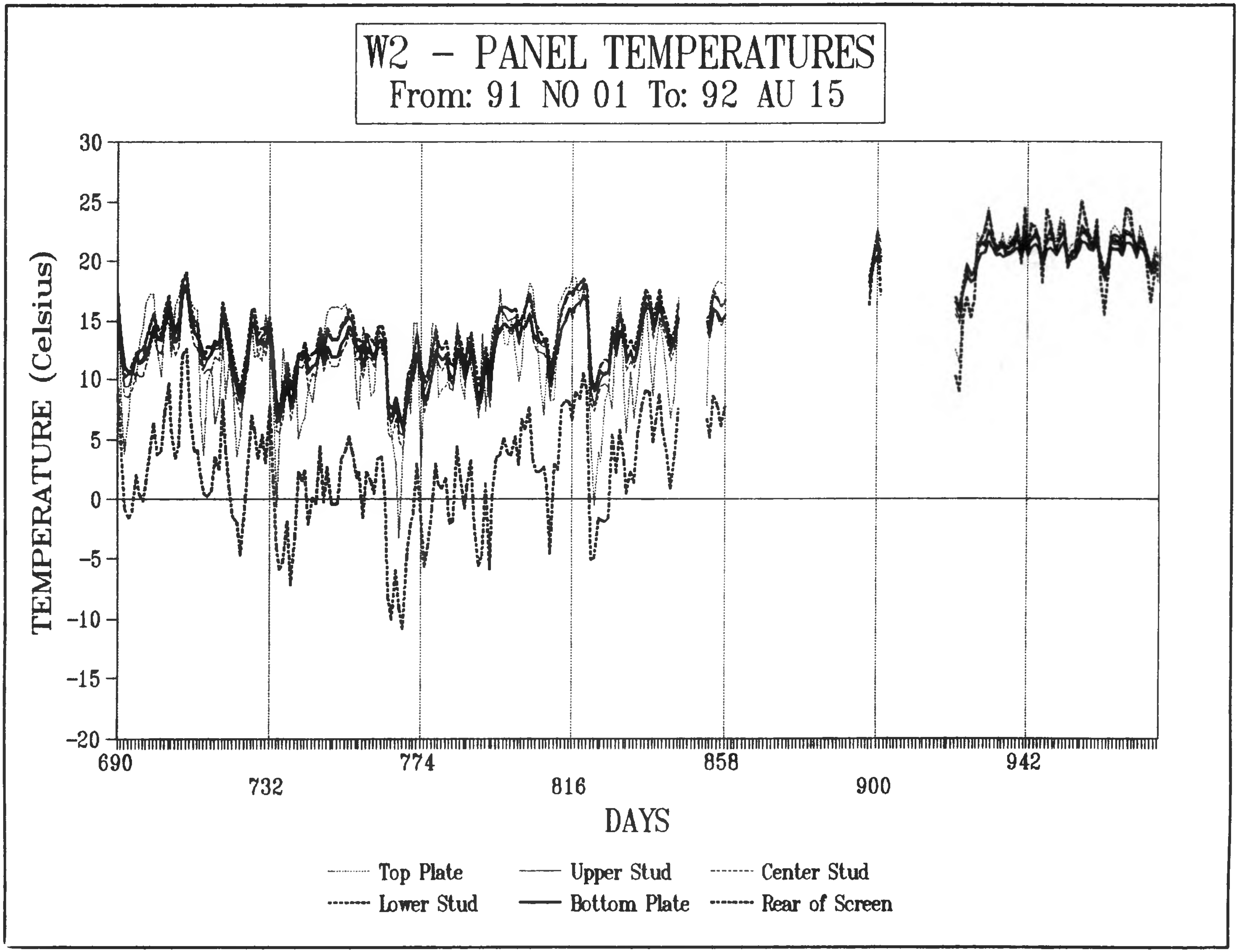


E2 - PANEL TEMPERATURES
From: 91 NO 01 To: 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Cavity

PANEL W2-STUD TEMPERATURES, DAILY

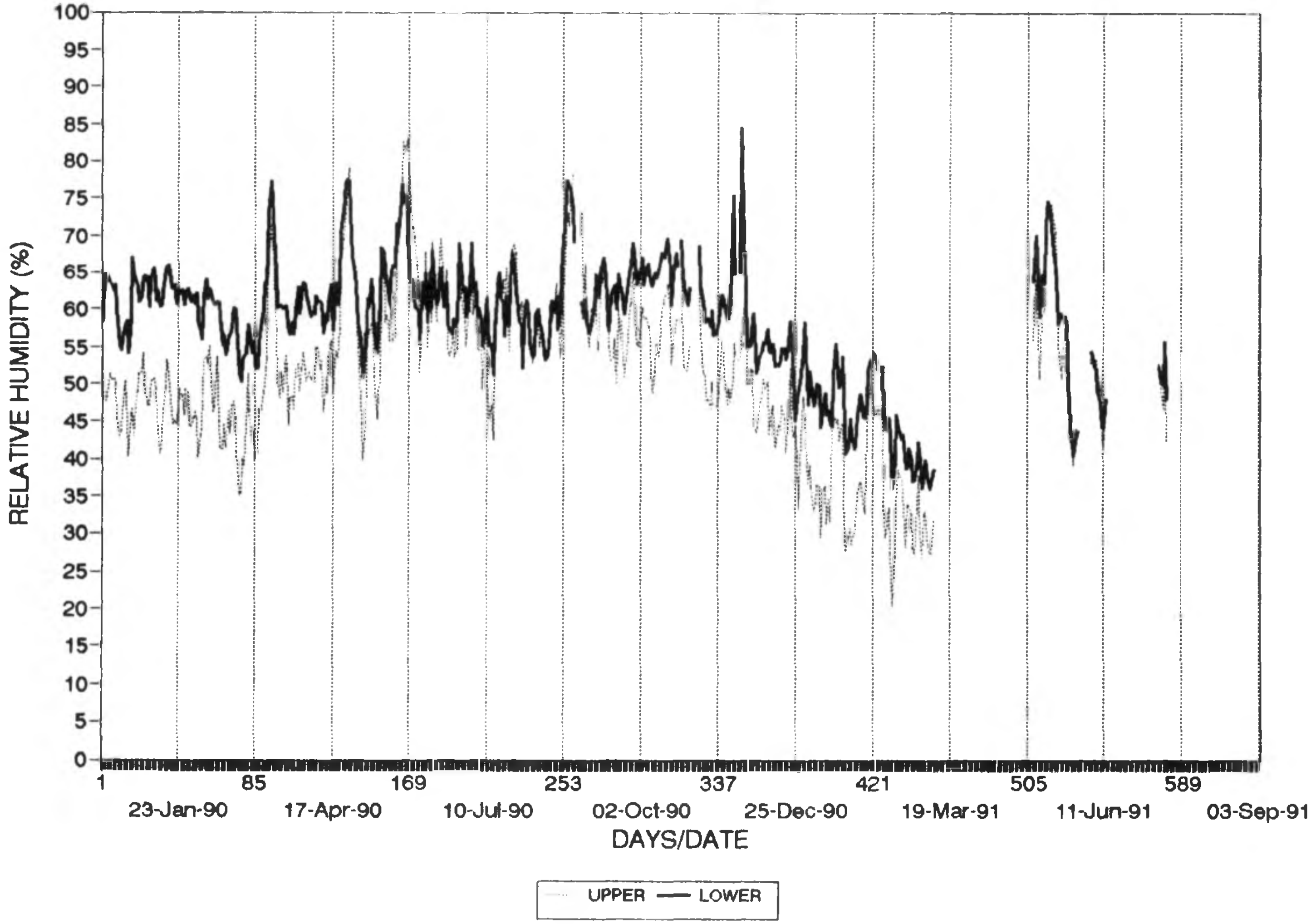
DEC. 12/89 TO JULY 15/91

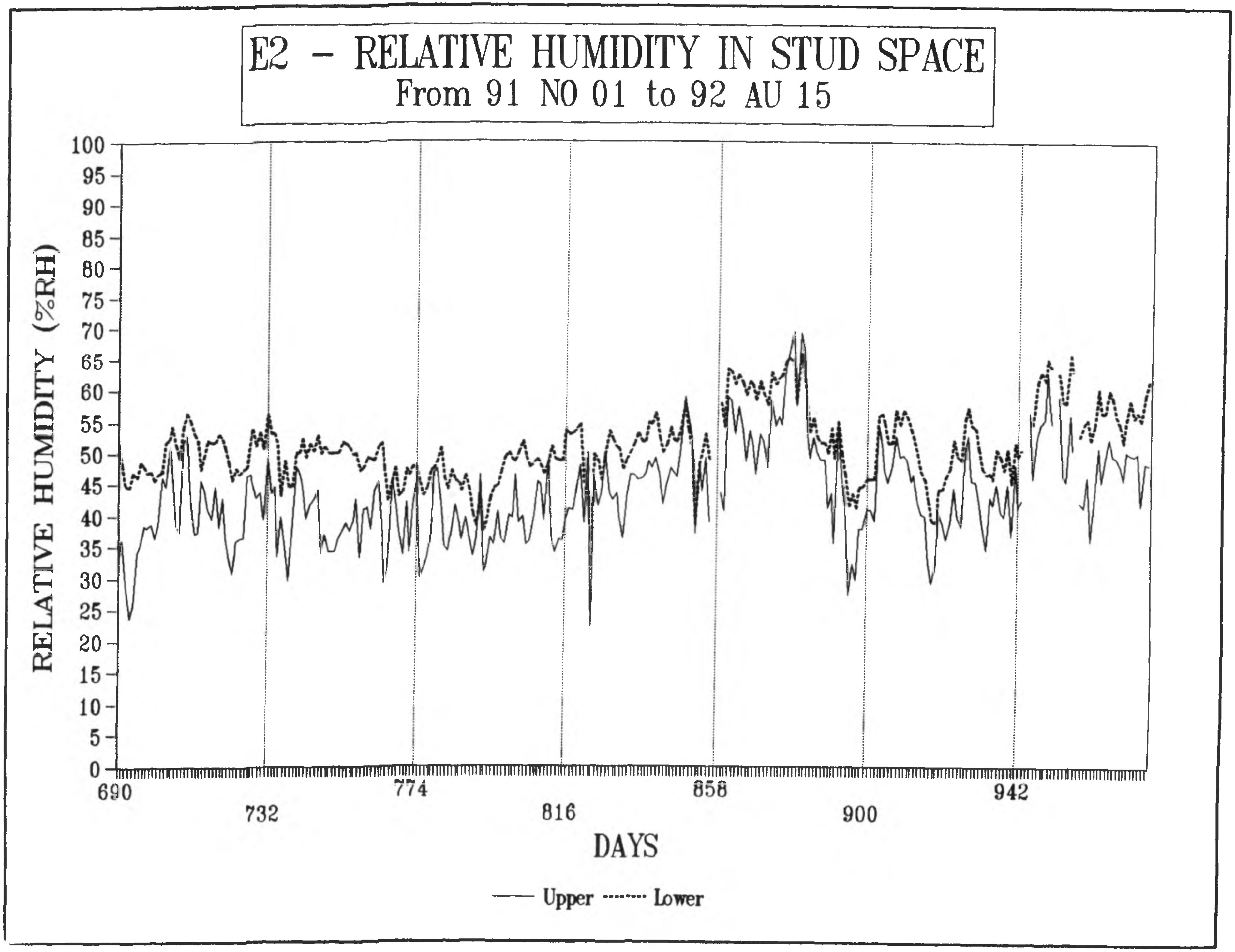


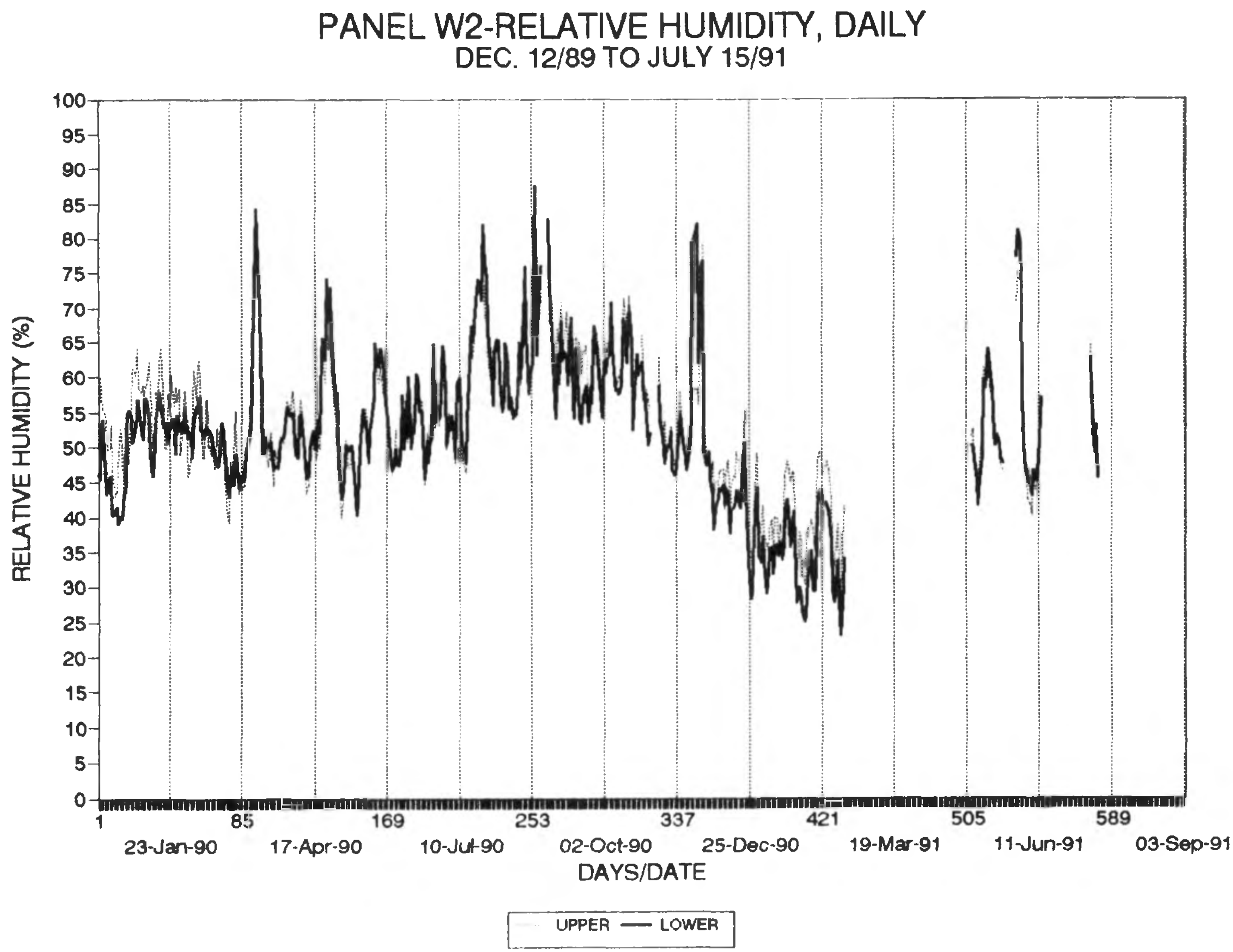


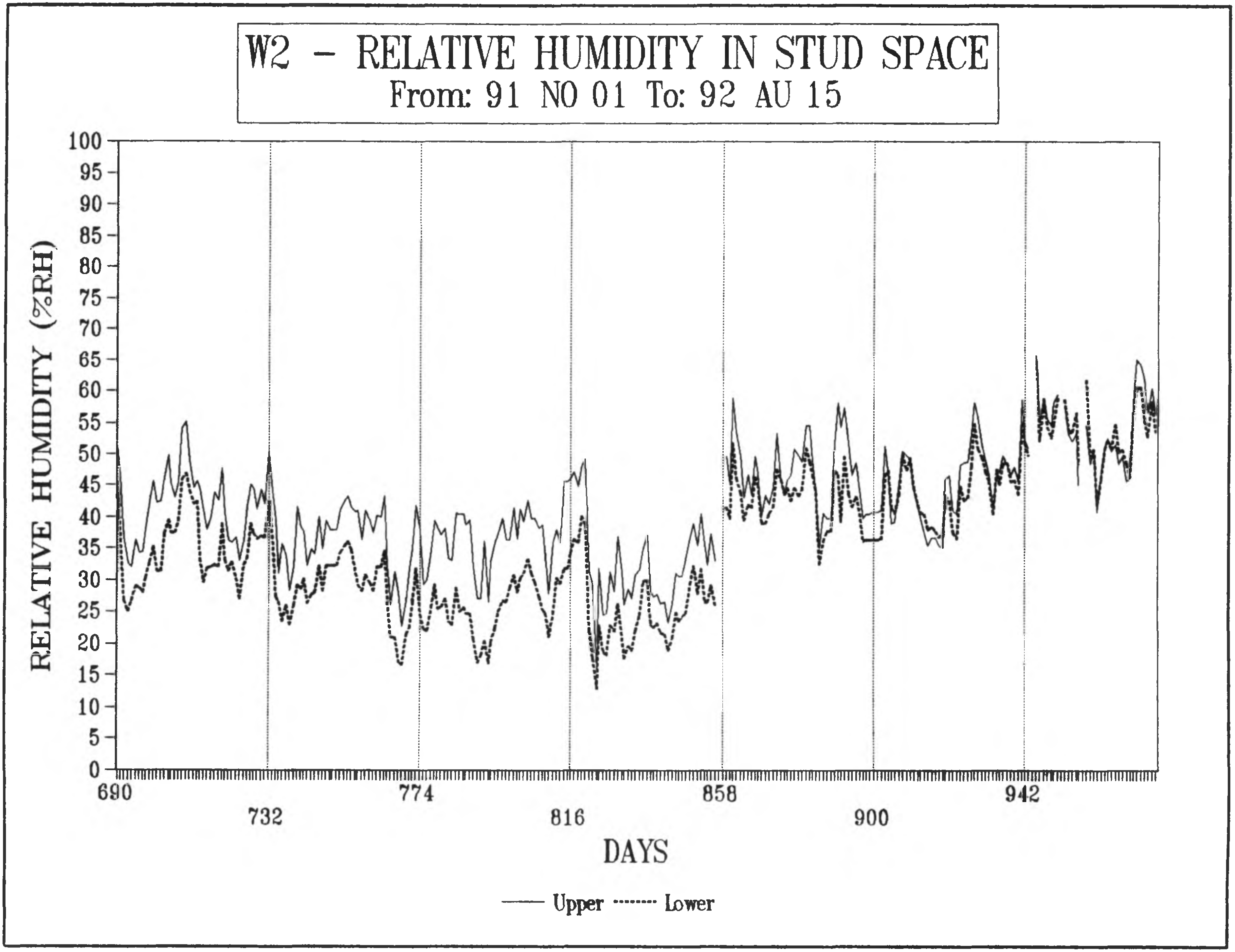
W2 - PANEL TEMPERATURES
From: 91 NO 01 To: 92 AU 15
TEMPERATURE (Celsius)
30
25
20
15
10
5
0
-5
-10
-15
-20
690
732
774
816
858
900
942
DAYS
Top Plate
Upper Stud
Center Stud
Lower Stud
Bottom Plate
Rear of Screen

PANEL E2-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91




E2 - RELATIVE HUMIDITY IN STUD SPACE
From 91 NO 01 to 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower


PANEL W2-RELATIVE HUMIDITY, DAILY
DEC. 12/89 TO JULY 15/91
RELATIVE HUMIDITY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
85
169
253
337
421
505
589
23-Jan-90
17-Apr-90
10-Jul-90
02-Oct-90
25-Dec-90
19-Mar-91
11-Jun-91
03-Sep-91
DAYS/DATE
UPPER
LOWER



W2 - RELATIVE HUMIDITY IN STUD SPACE
From: 91 NO 01 To: 92 AU 15
RELATIVE HUMIDITY (%RH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
690
732
774
816
858
900
942
DAYS
Upper
Lower