FIGURE 1

EFFECT OF SURFACE AREA ON BULK ACTIVITY AND SELECTIVITY

(Fixed-Bed Reactor - CO/H_2=1, 1000 hr^{-1}, 300 psig)

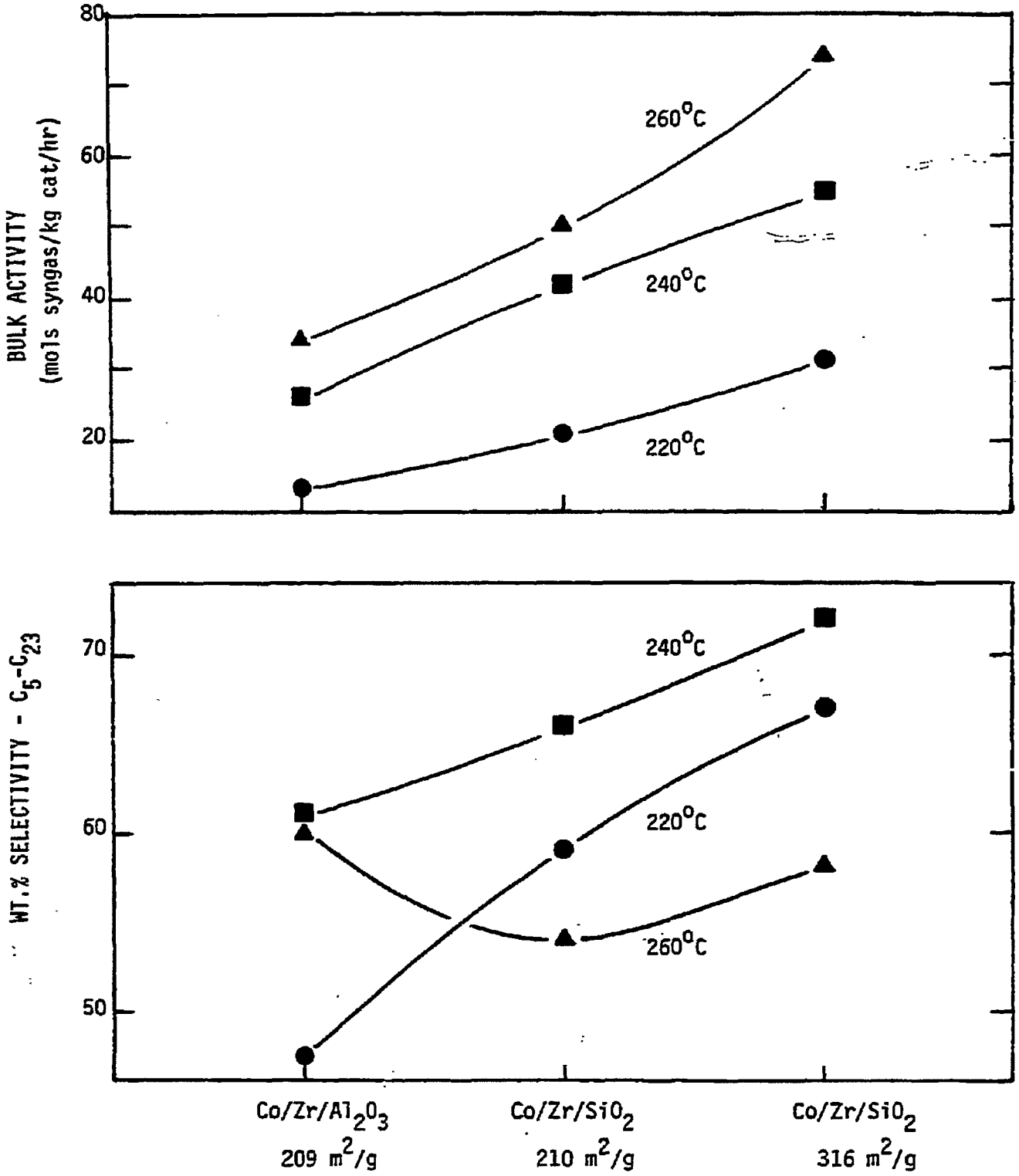


FIGURE 2

EFFECT OF COBALT LOADING ON
BULK ACTIVITY OF $Co/Zr/SiO_2$ CATALYST
(Fixed Bed Reactor - CO/H_2=1, 1000 hr^{-1}, 300 psig)

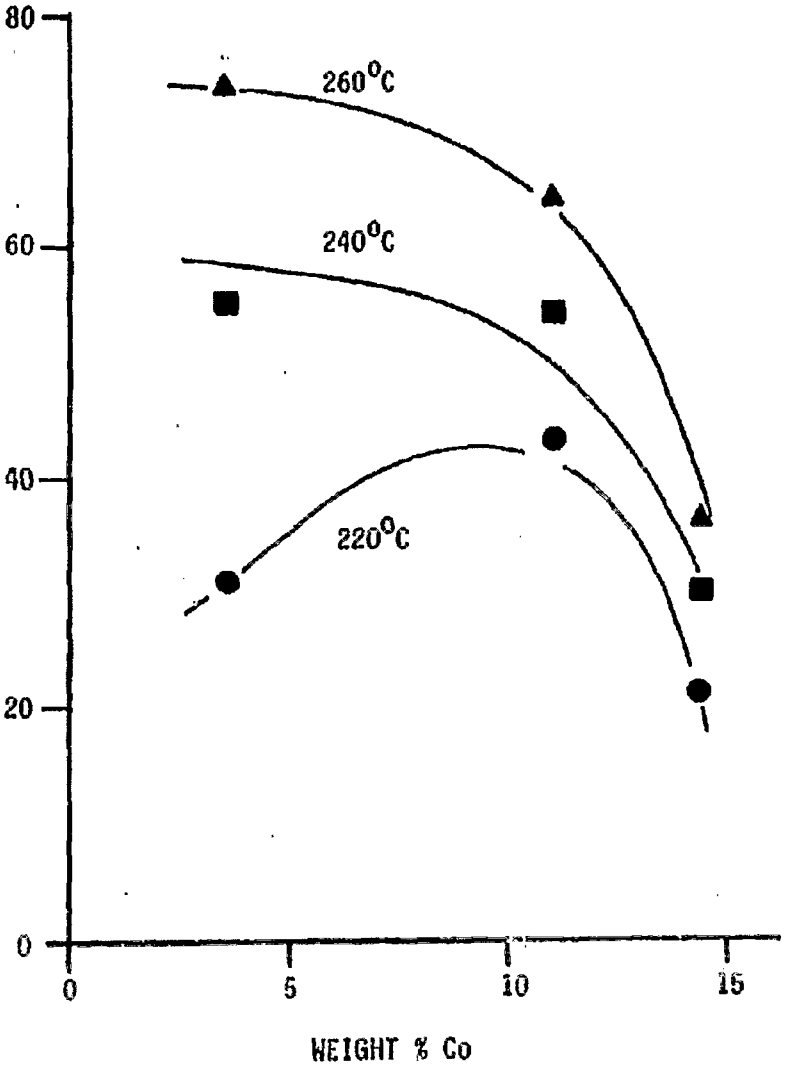


FIGURE 3

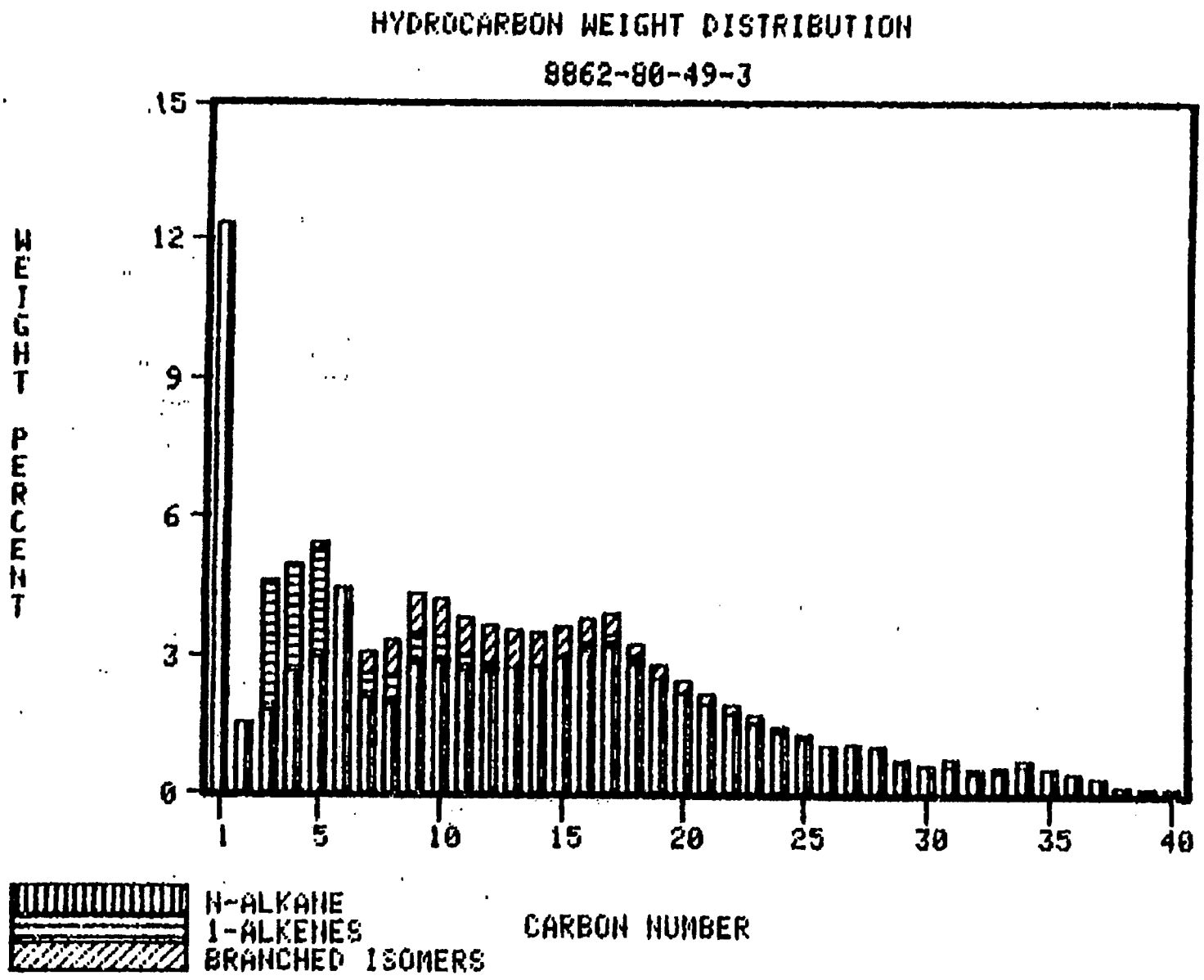

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-49-3
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 4

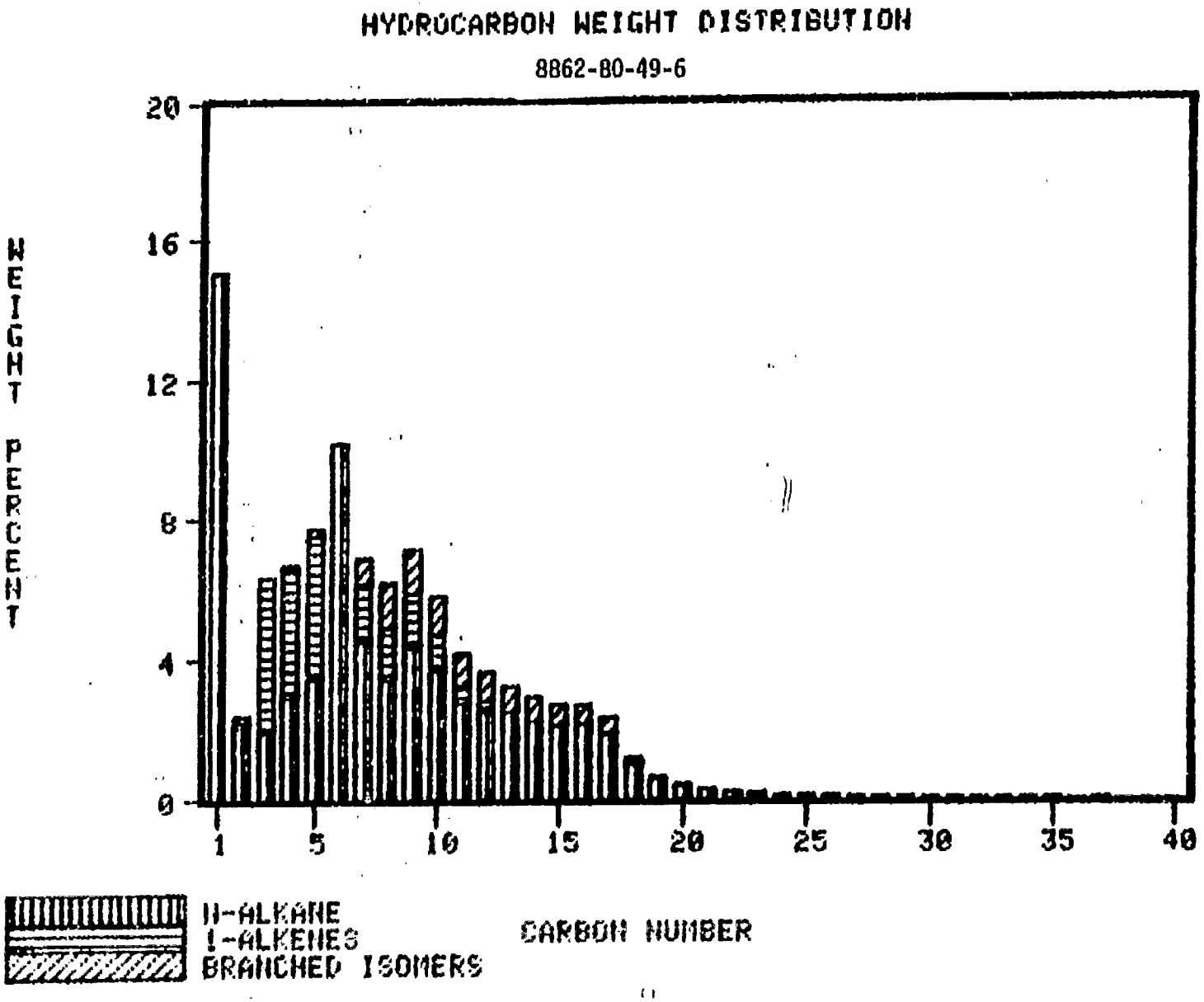

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-49-6
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 5

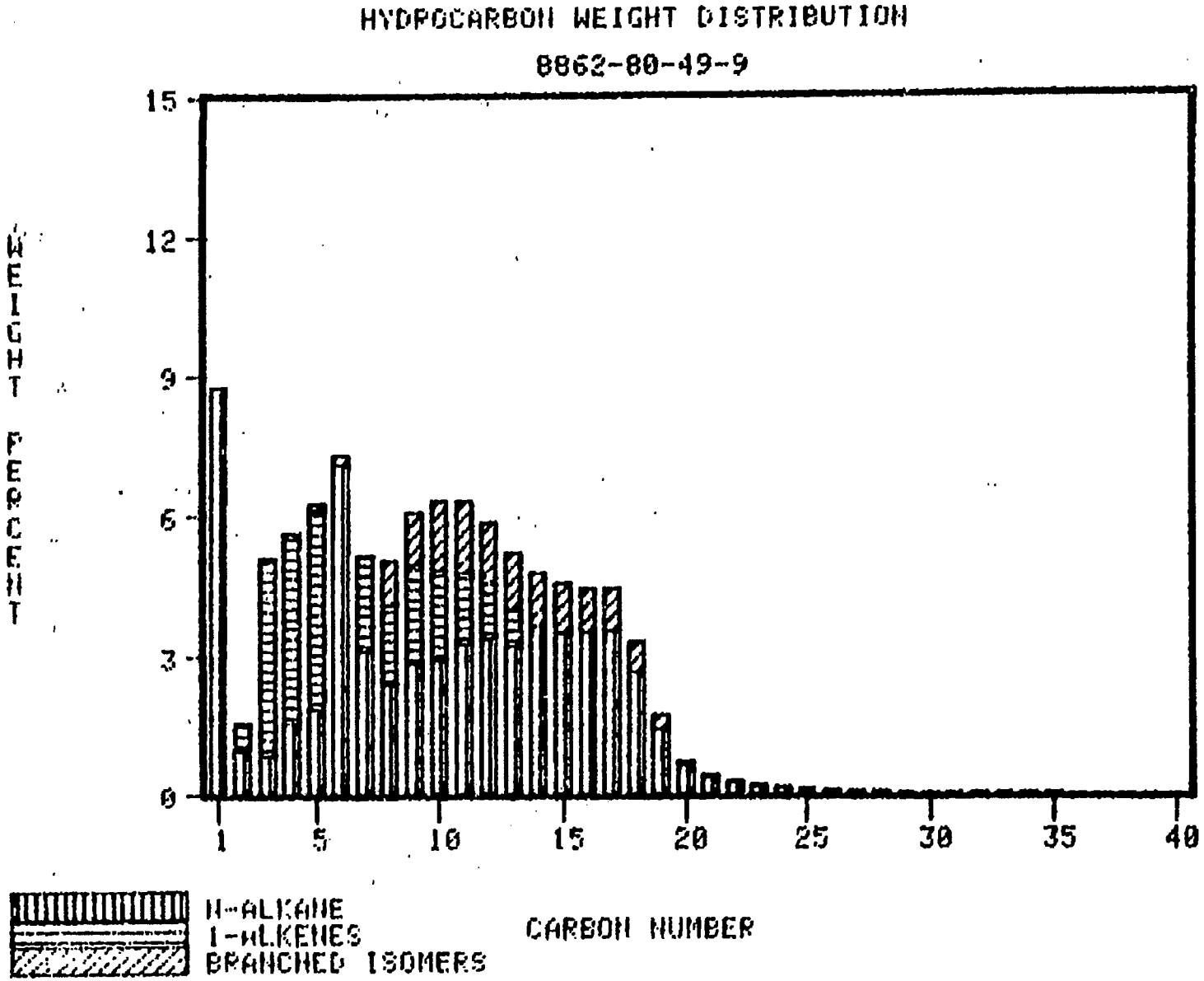

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-49-9
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 6

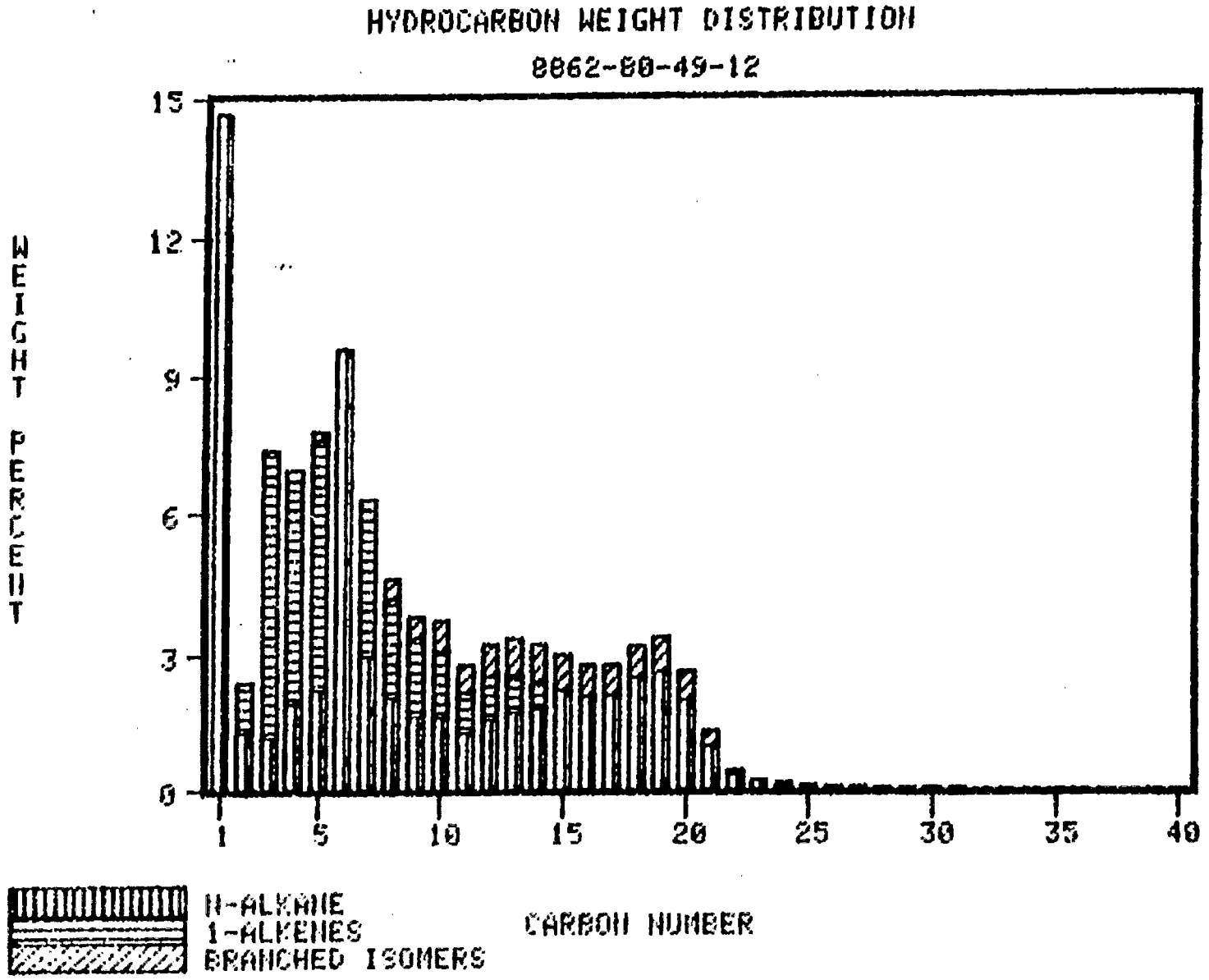

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-49-12
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 7

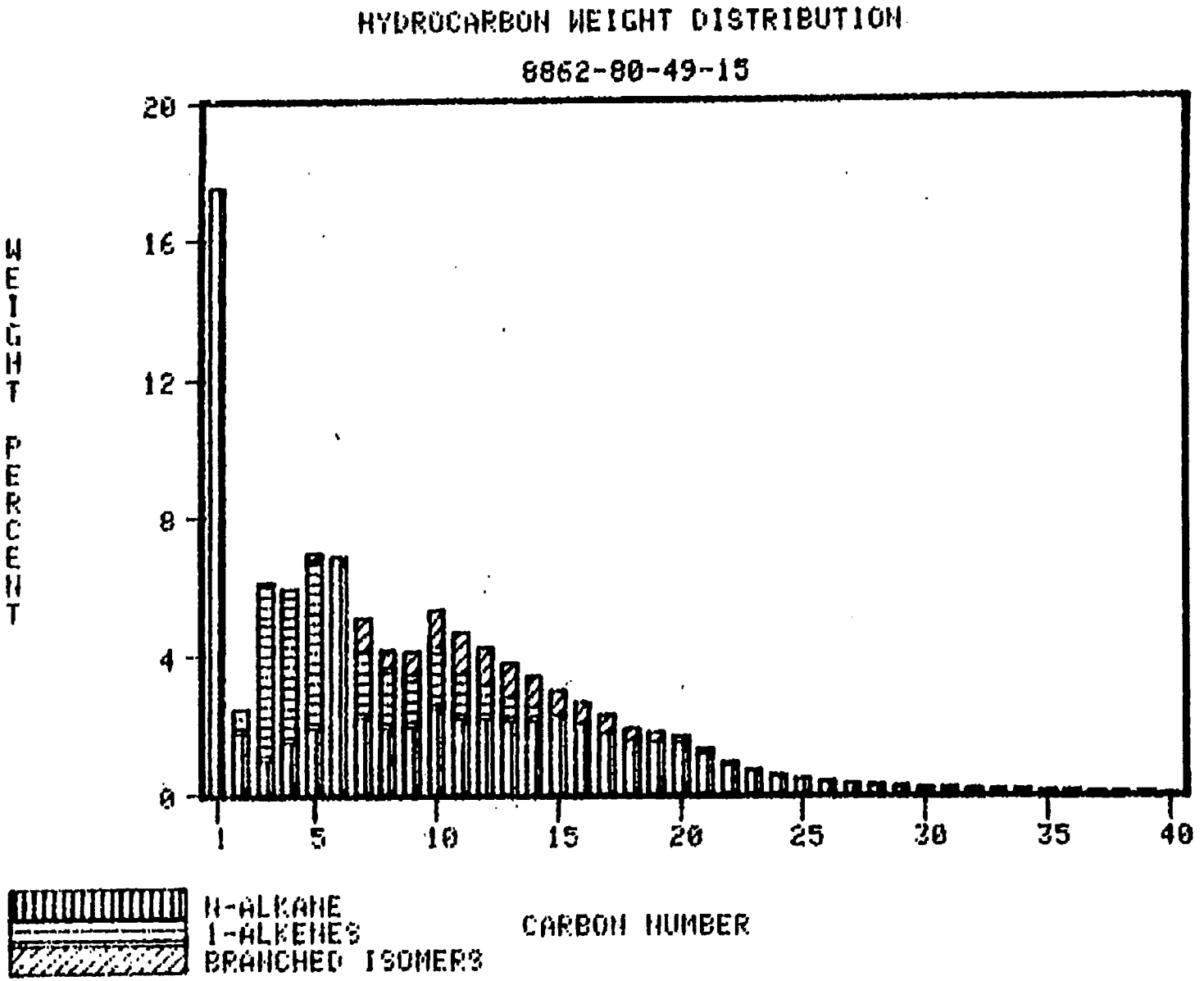

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-49-15
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 8

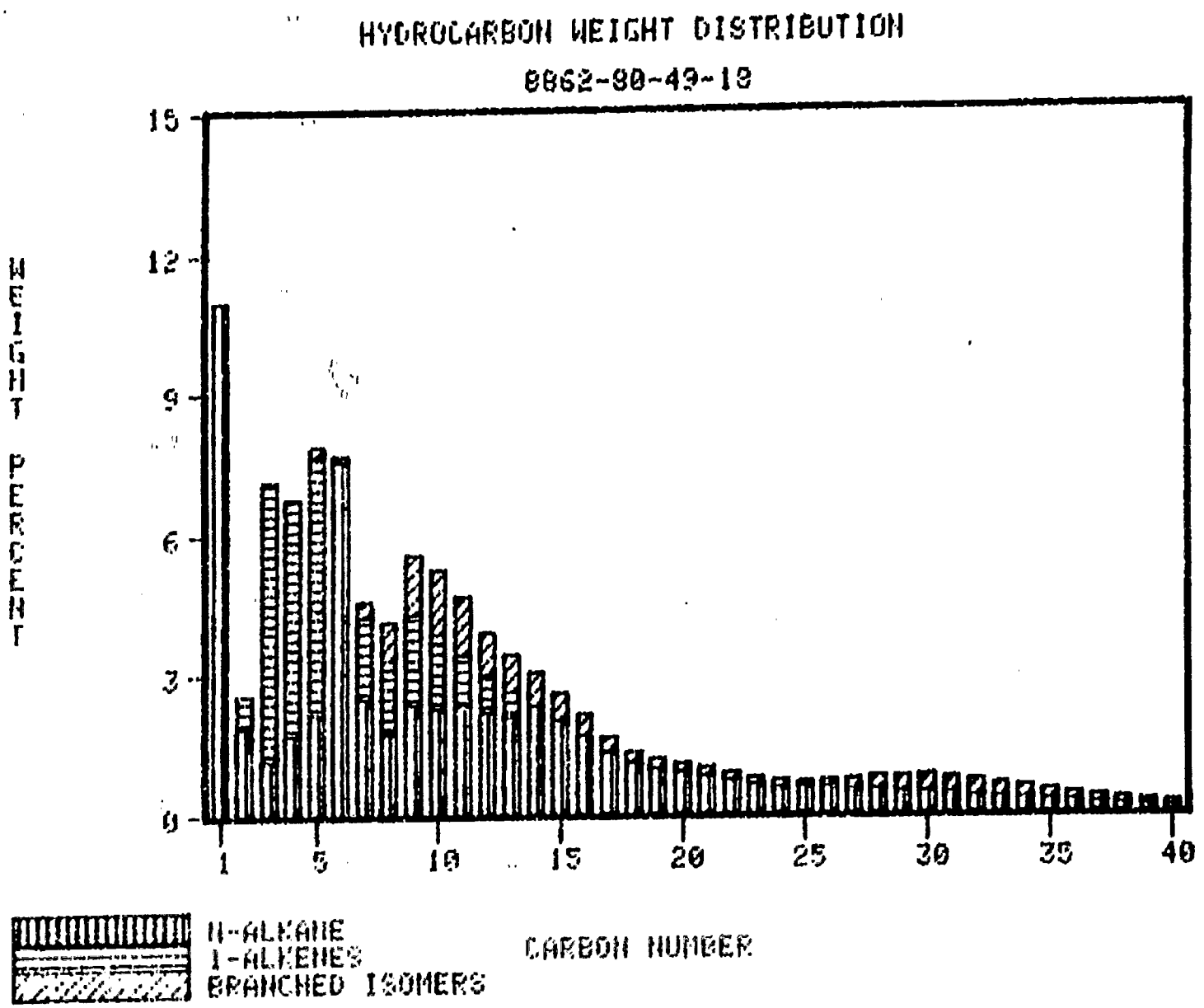

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-43-18
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 9

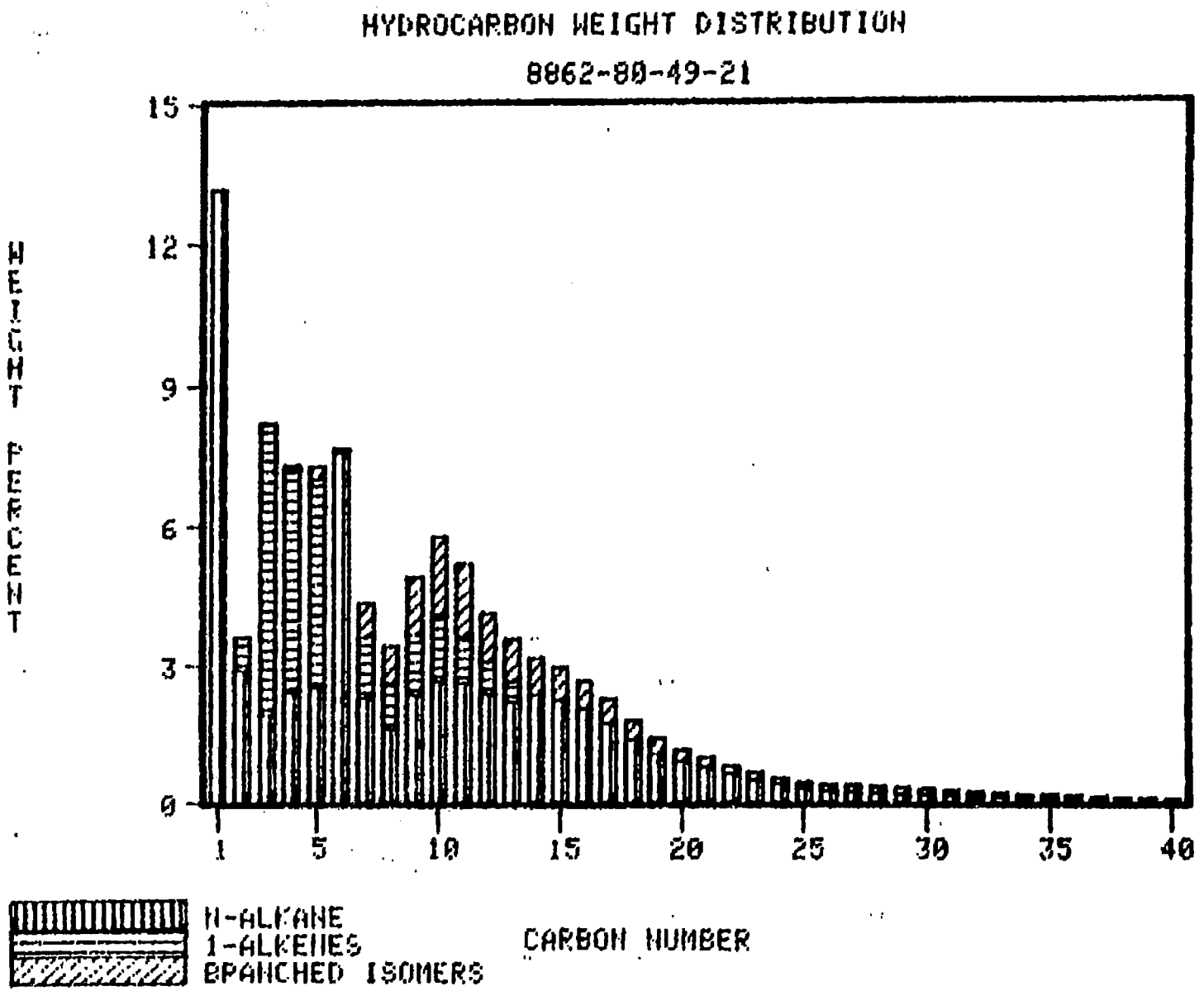

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-49-21
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 10

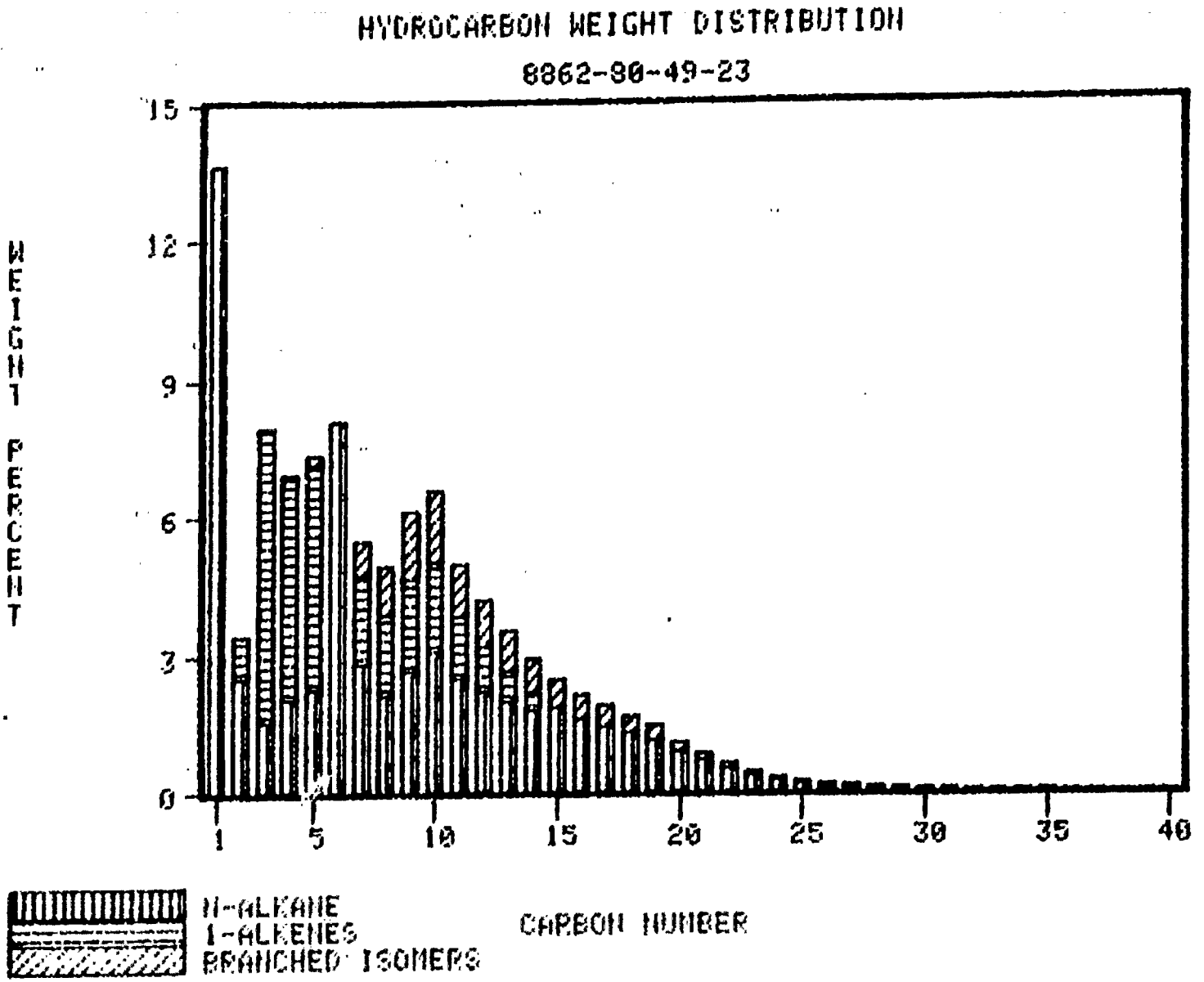

HYDROCARBON WEIGHT DISTRIBUTION
8862-80-49-23
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 11

HYDROCARBON WEIGHT DISTRIBUTION

8862-80-49-27

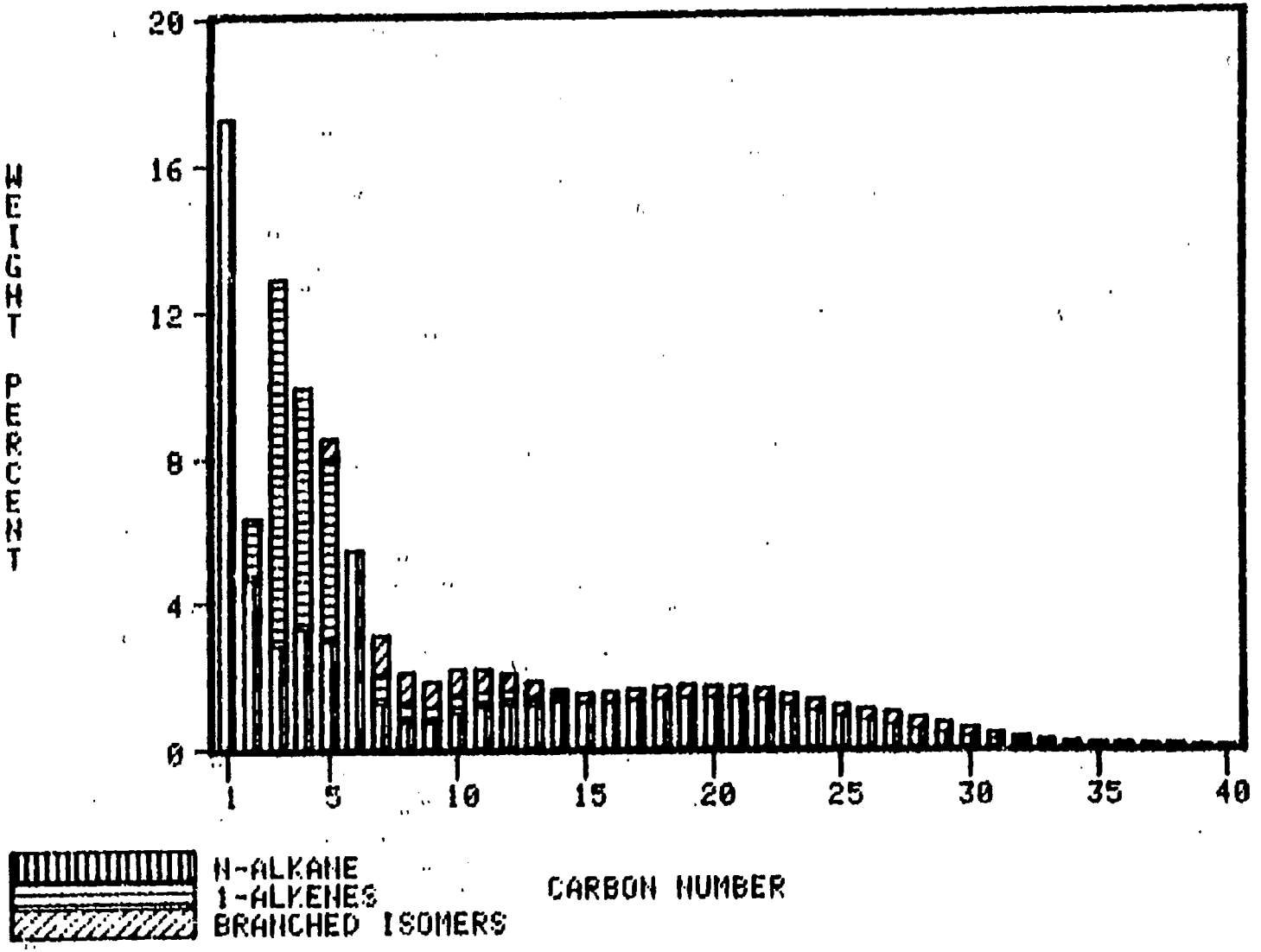


FIGURE 12

HYDROCARBON WEIGHT DISTRIBUTION

8862-80-49-30

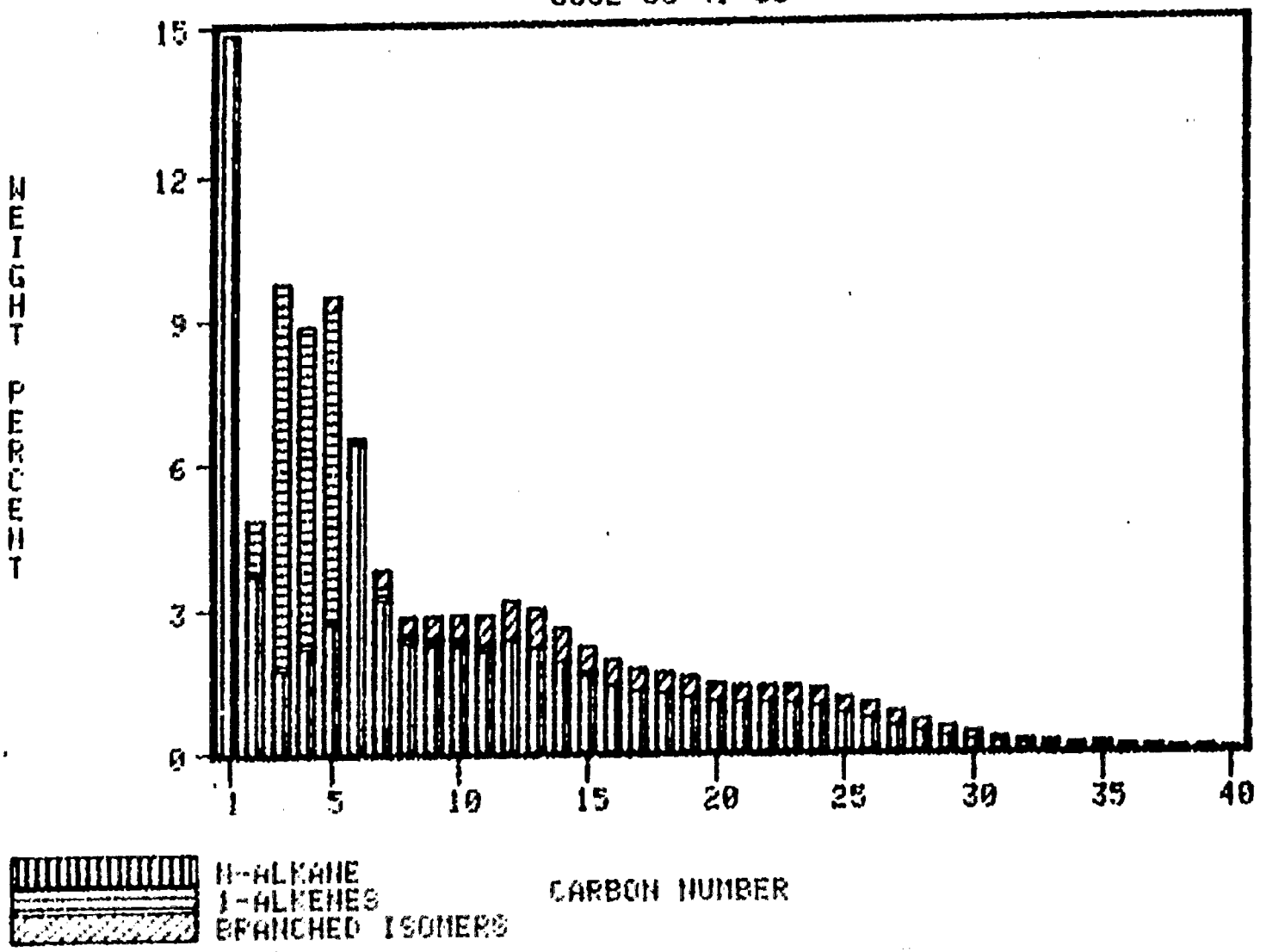


FIGURE 13

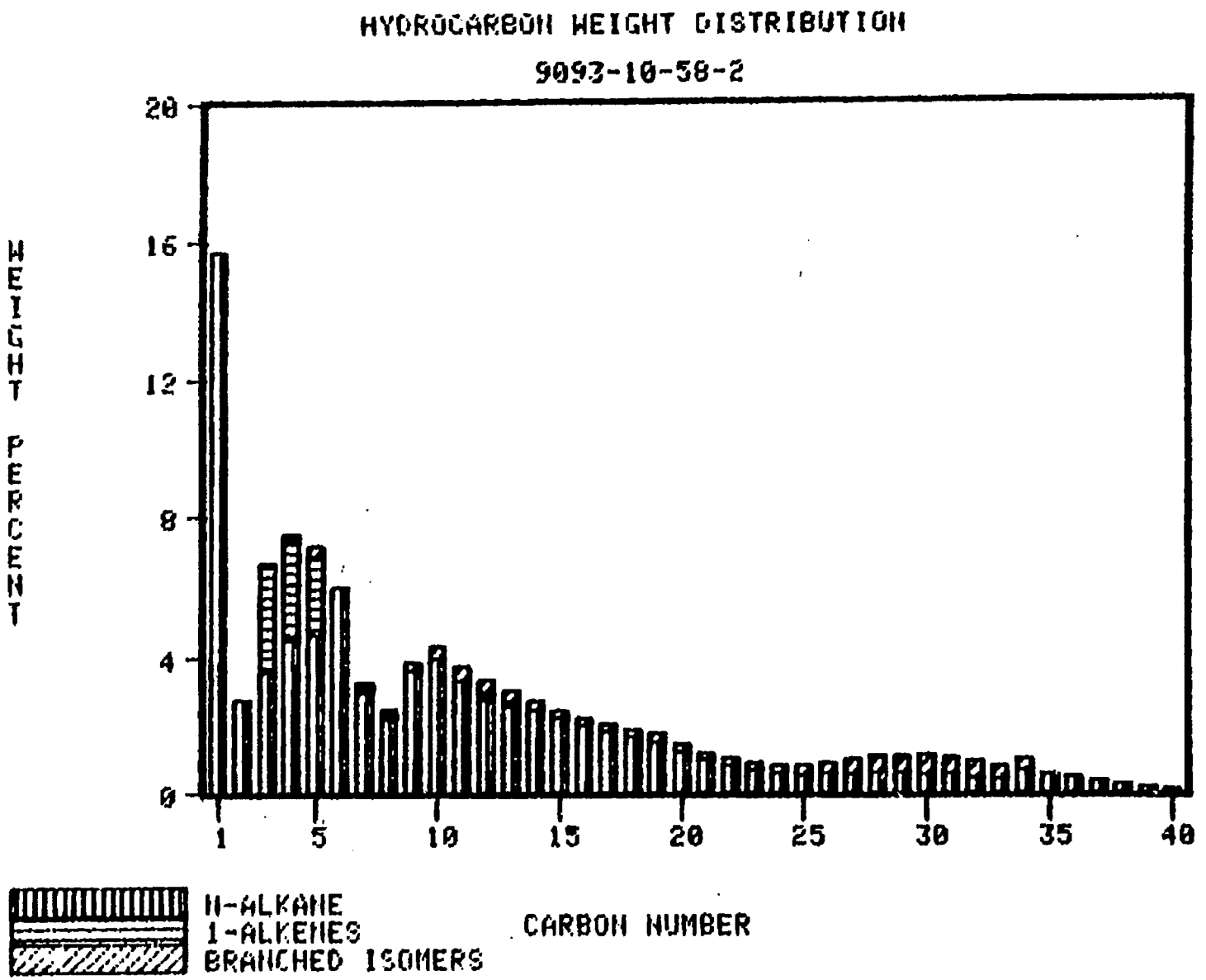

HYDROCARBON WEIGHT DISTRIBUTION
9093-10-58-2
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 14

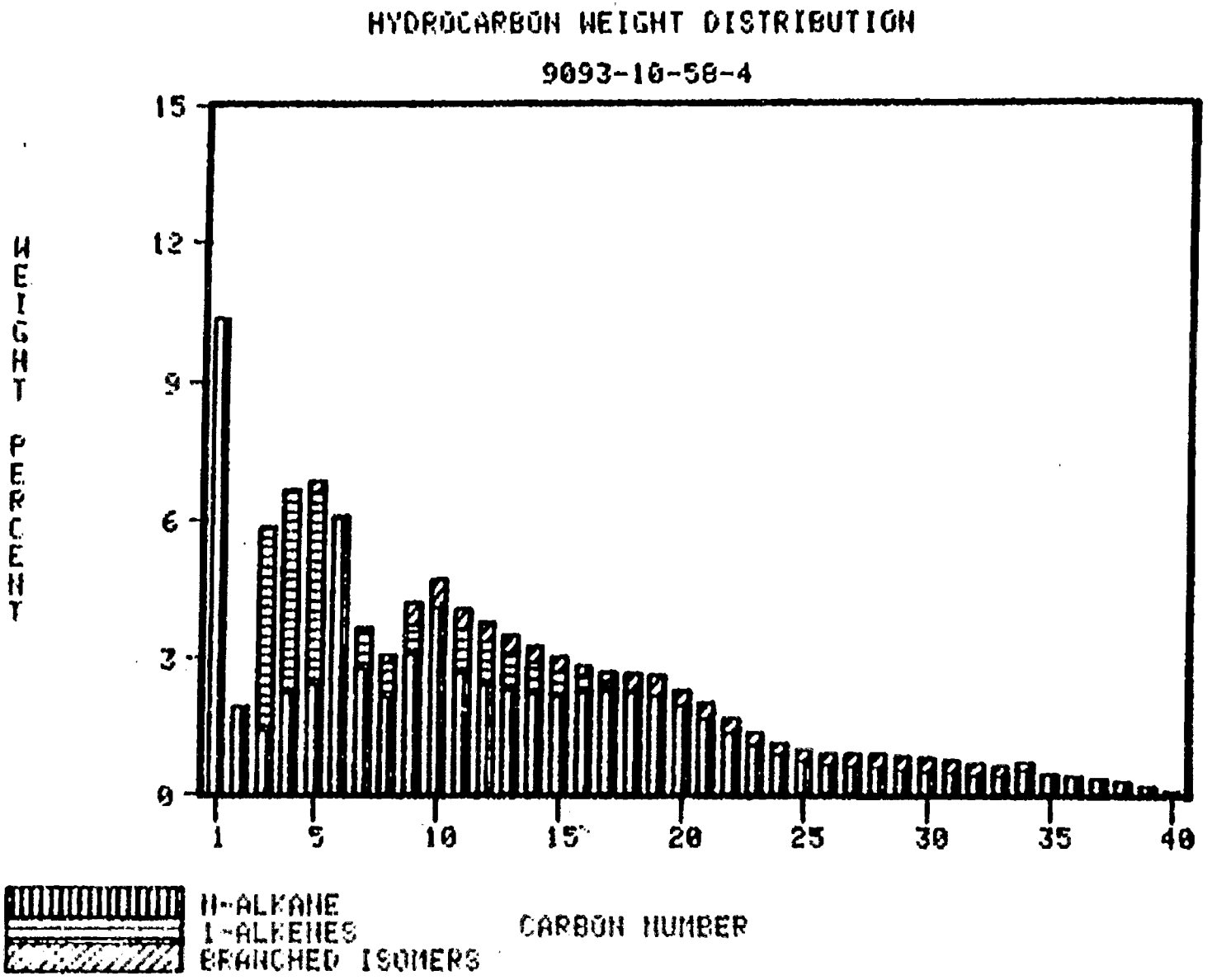

HYDROCARBON WEIGHT DISTRIBUTION
9093-10-58-4
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 15

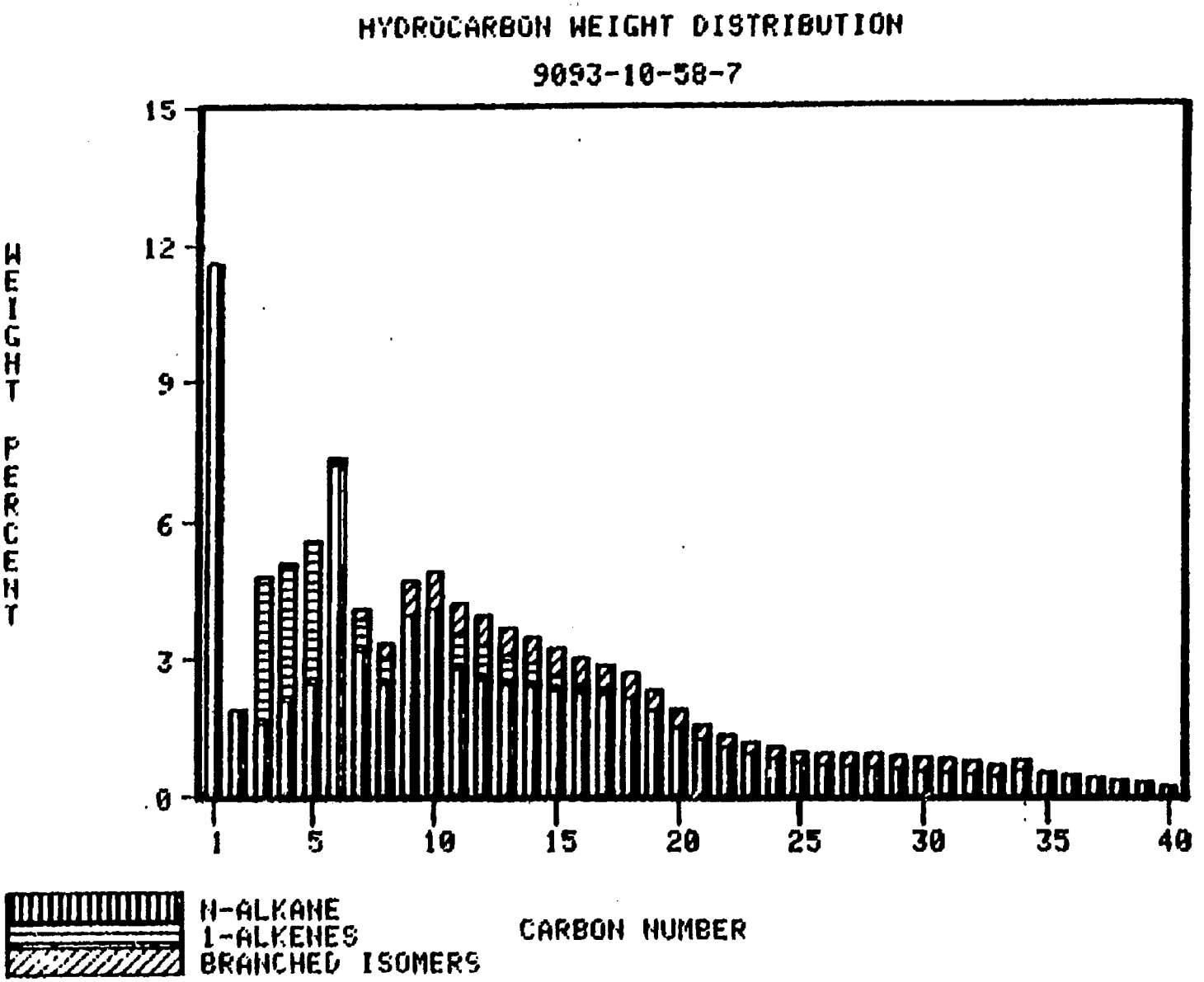

HYDROCARBON WEIGHT DISTRIBUTION
9093-10-58-7
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 16

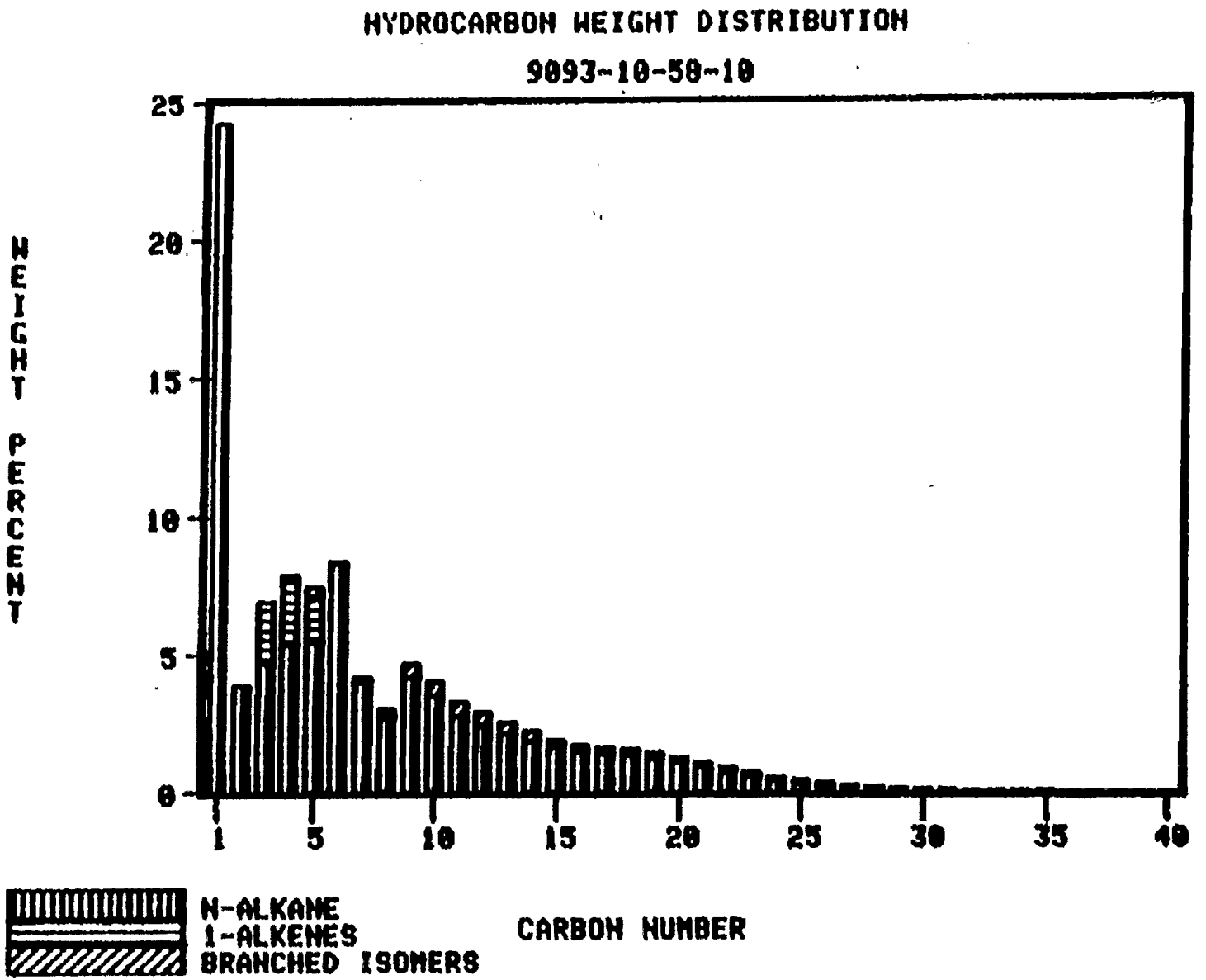

HYDROCARBON WEIGHT DISTRIBUTION
9093-10-58-10
WEIGHT PERCENT
25
20
15
10
5
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 17

HYDROCARBON WEIGHT DISTRIBUTION

9093-10-50-12

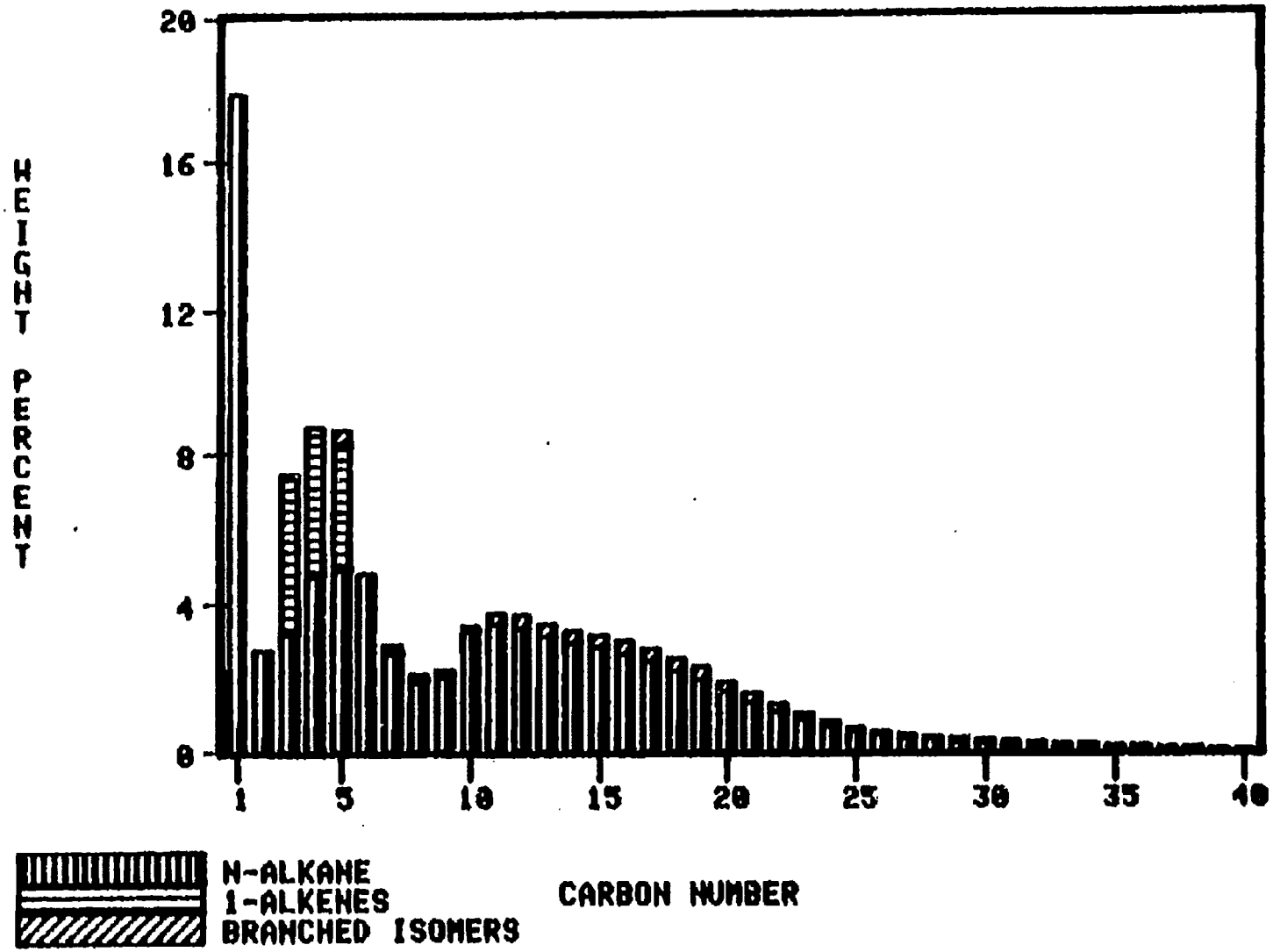


FIGURE 18

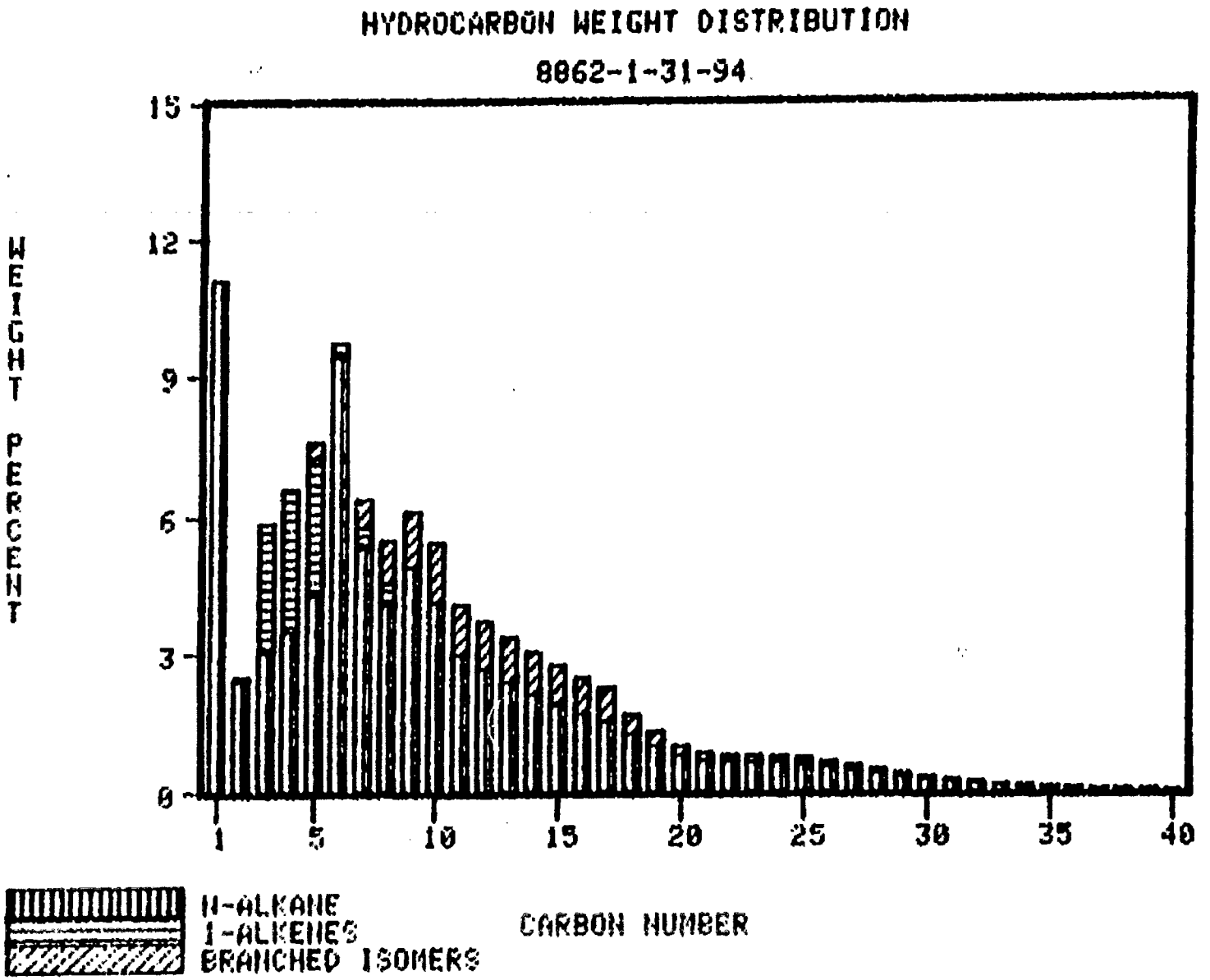

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-94
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 19

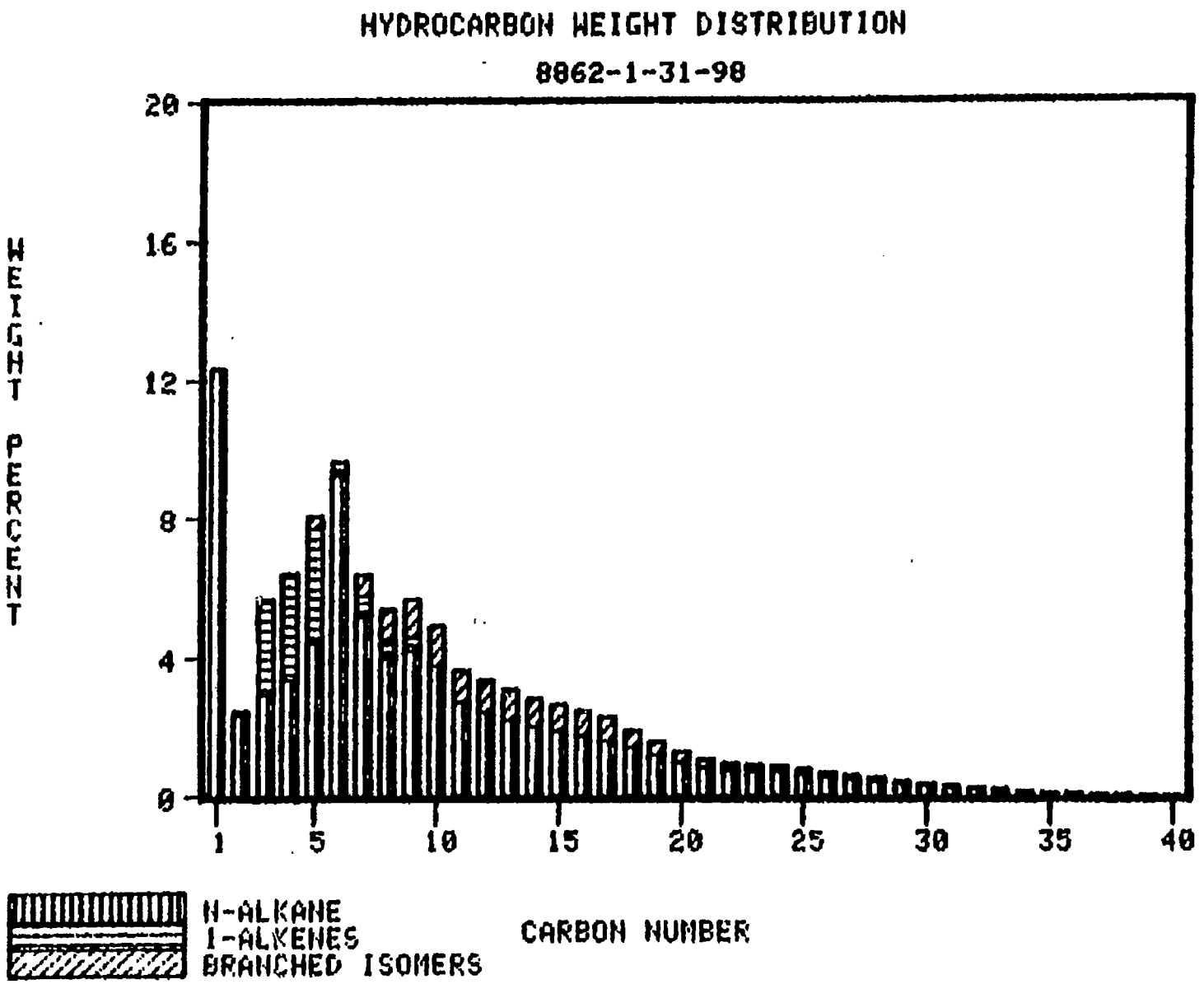

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-98
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 20

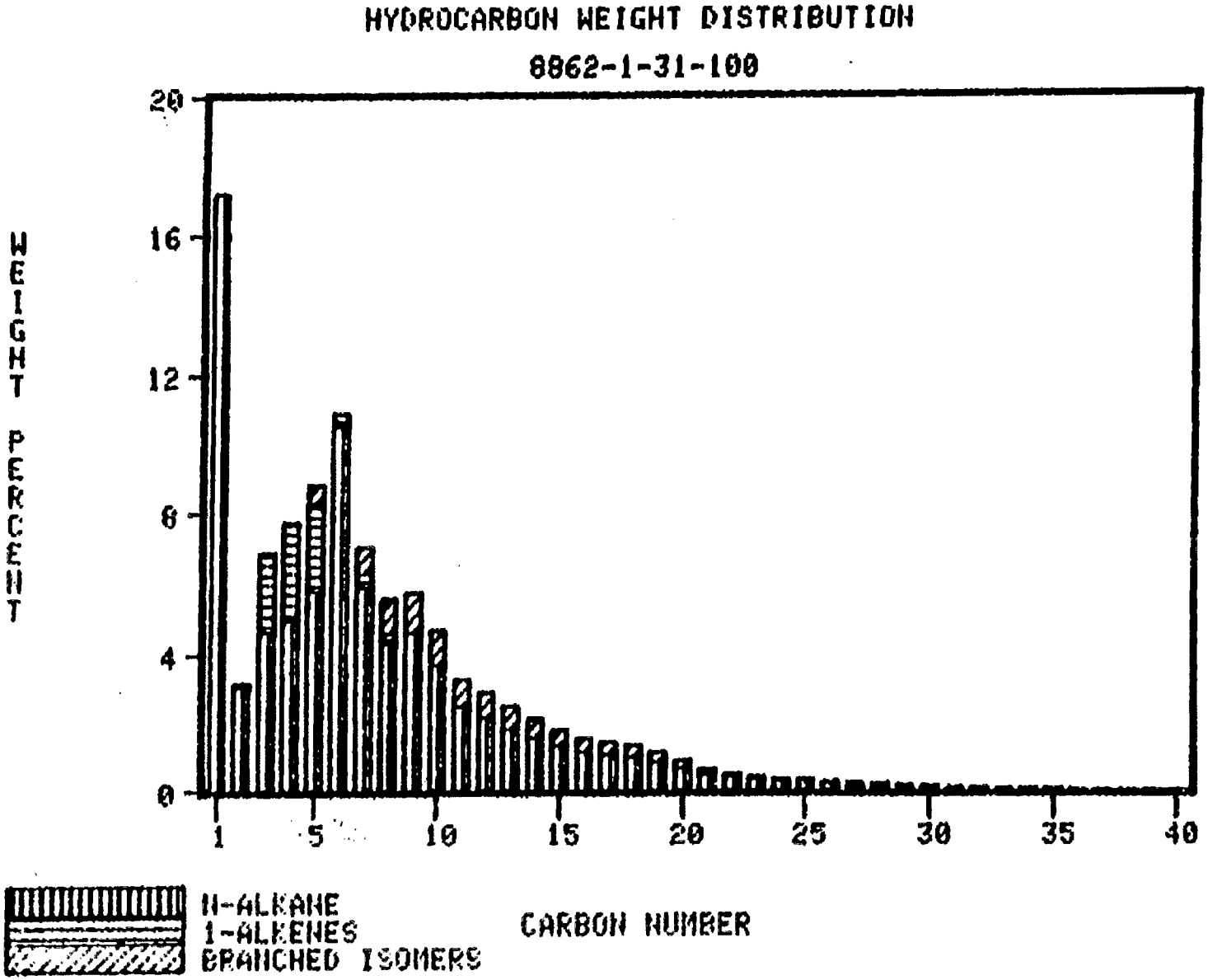

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-100
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 21

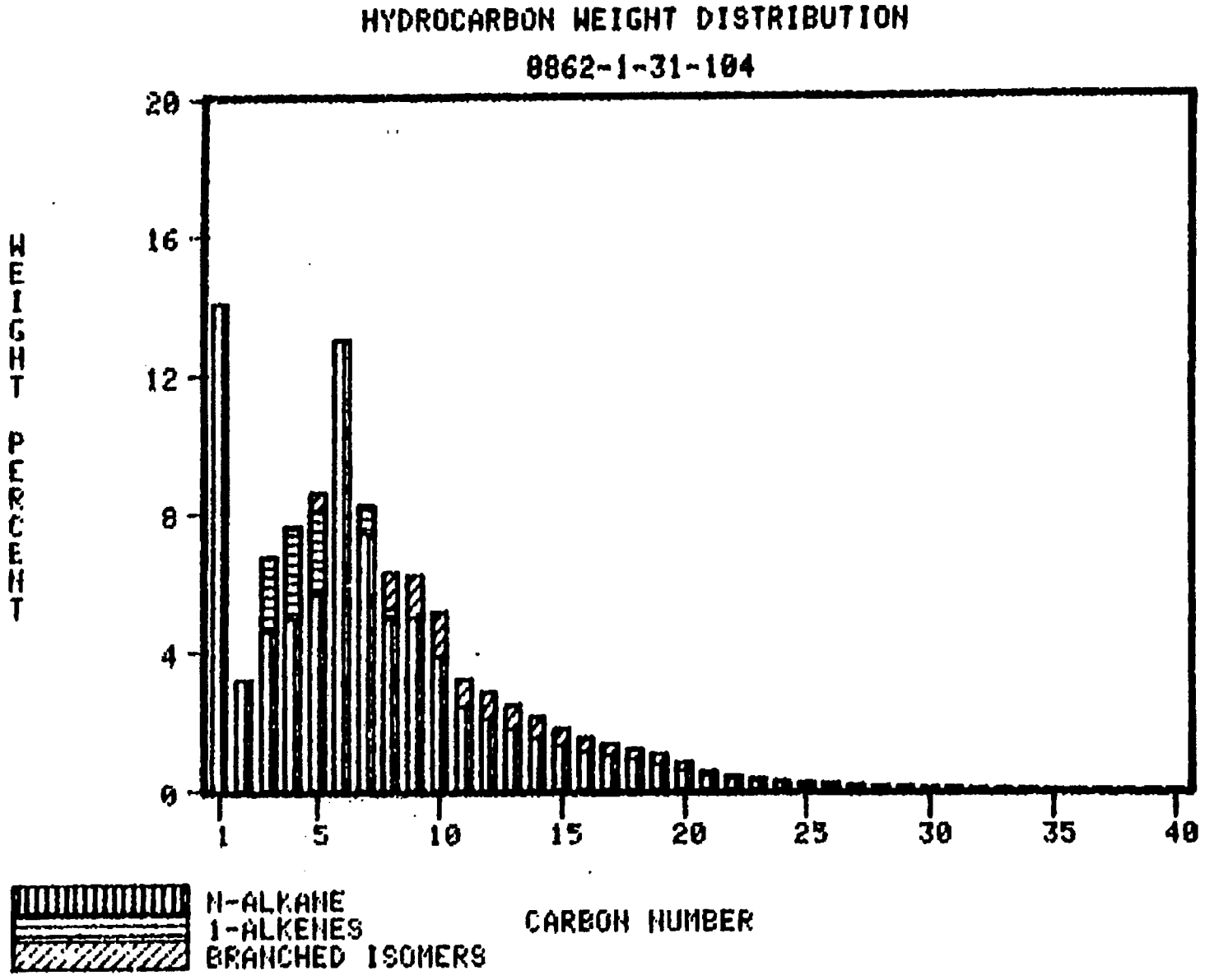

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-104
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 22

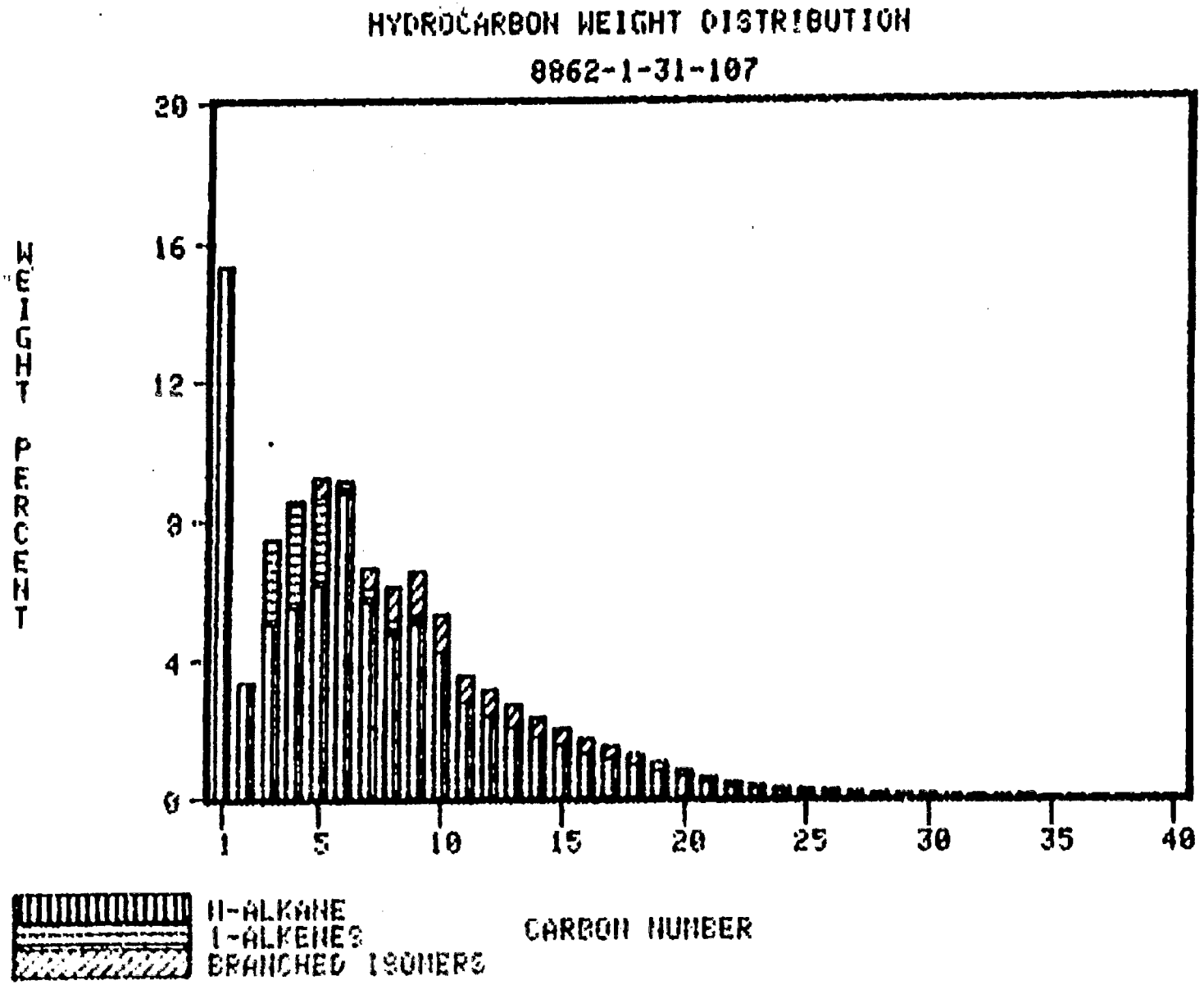

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-107
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 23

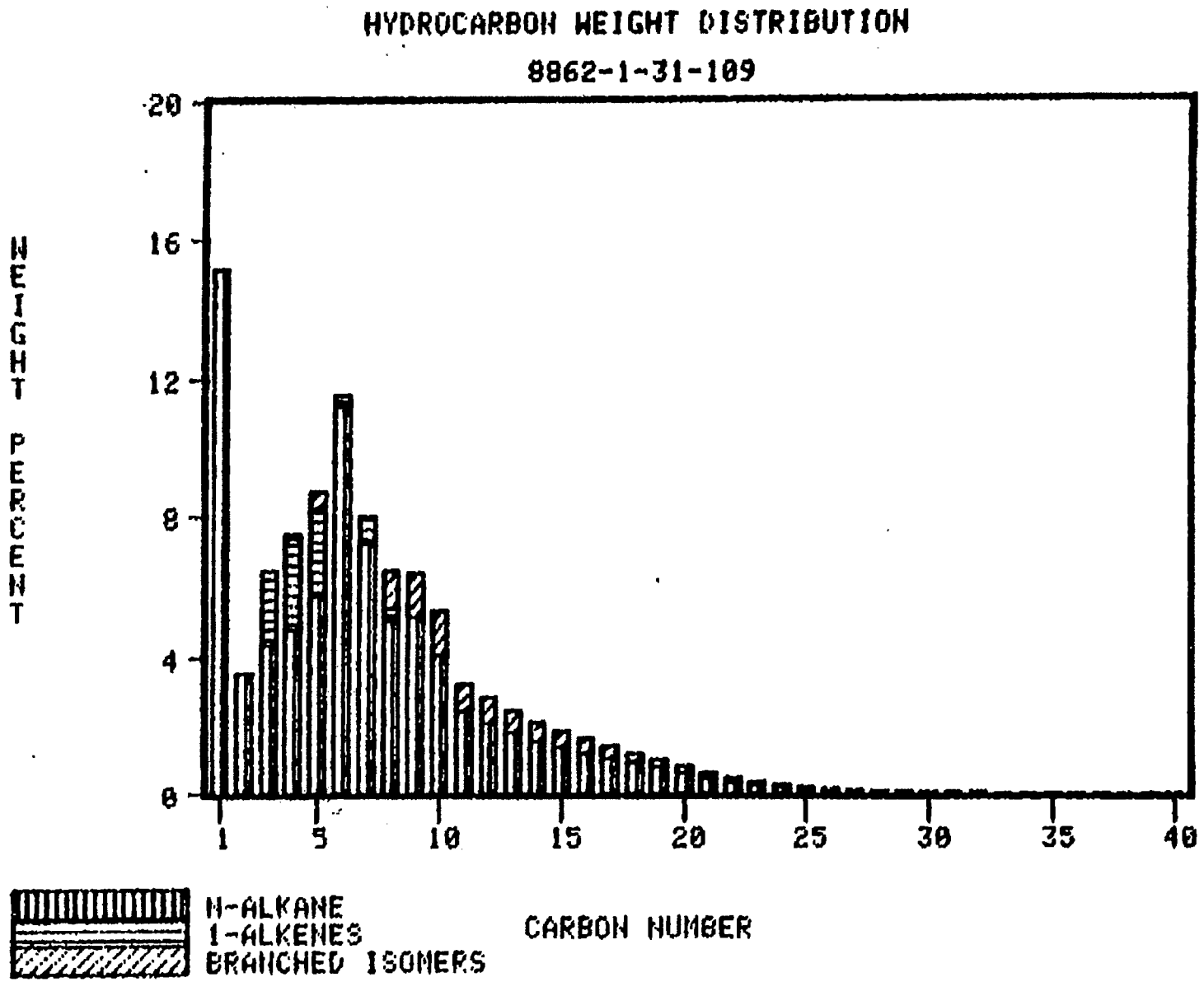

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-109
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 24

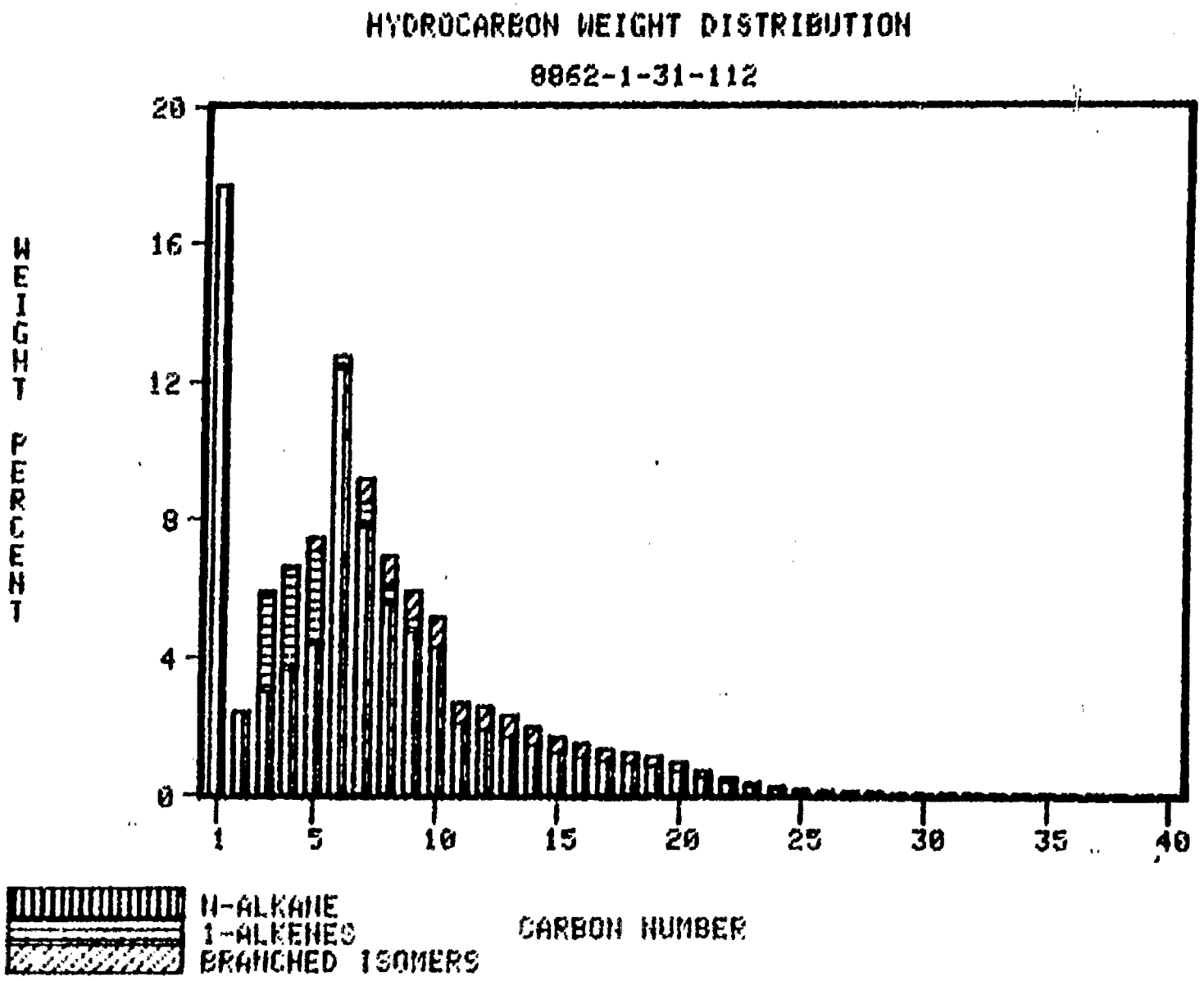

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-112
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 25

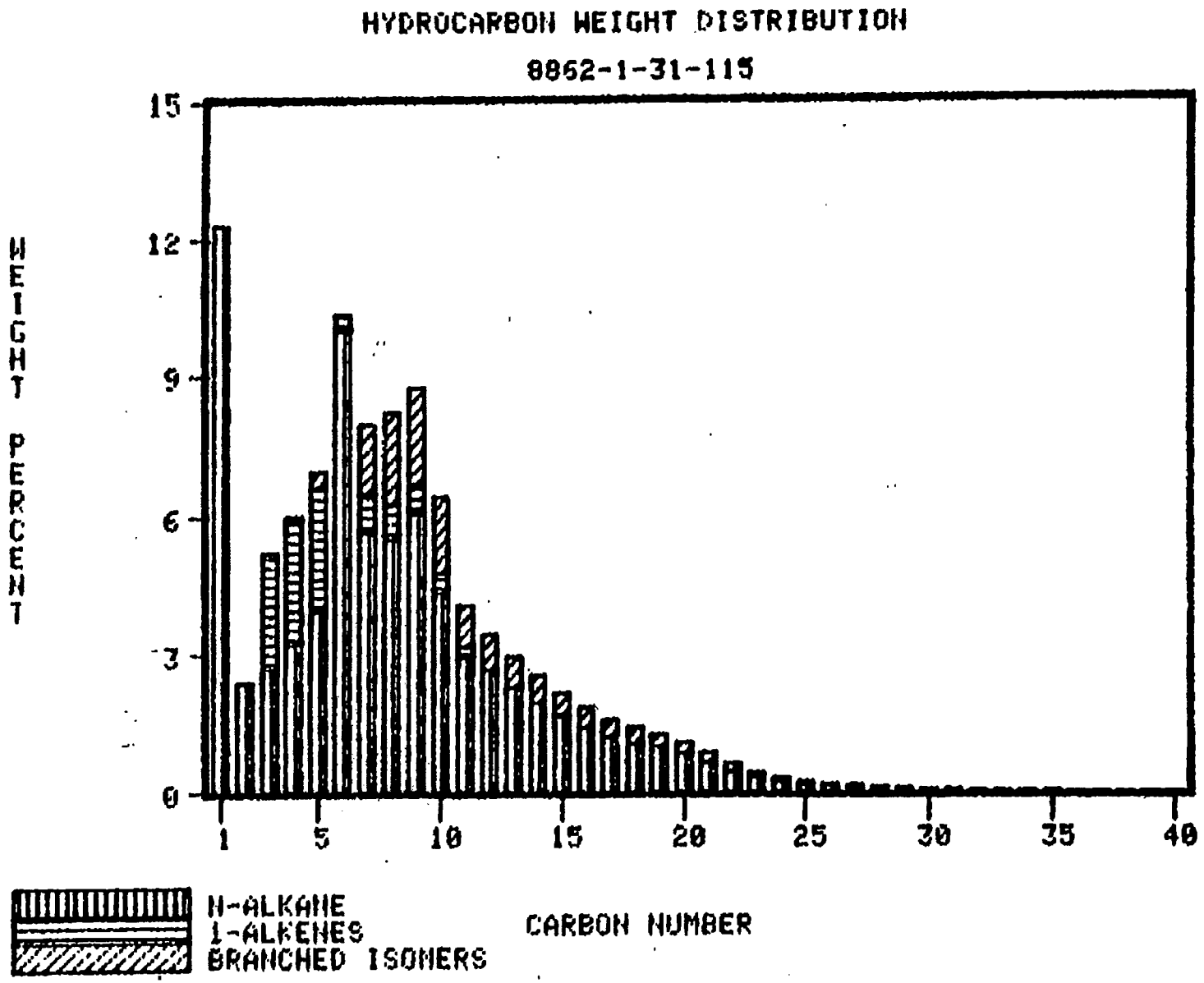

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-115
WEIGHT PERCENT
15
12
9
6
3
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 26

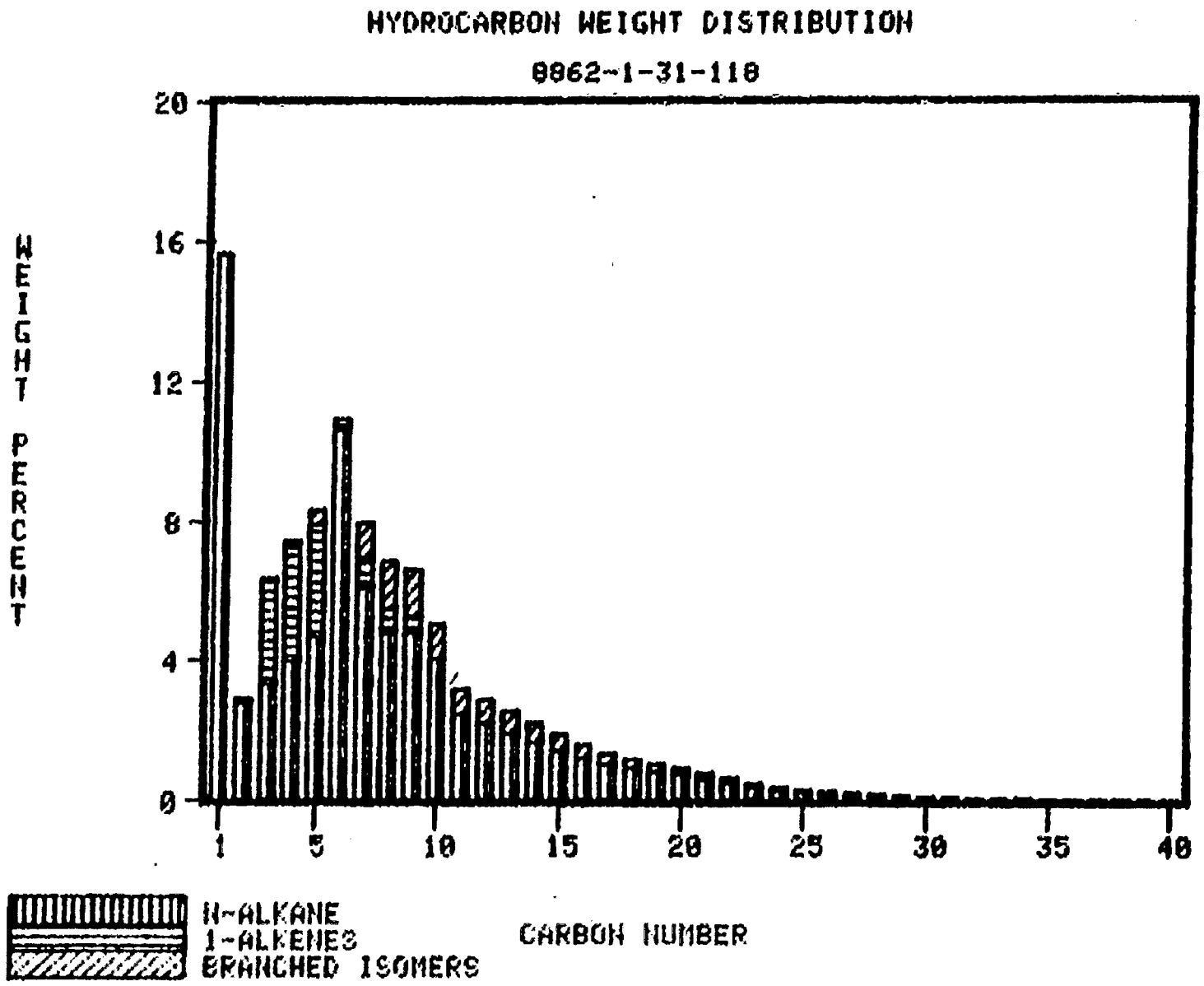

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-118
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 27

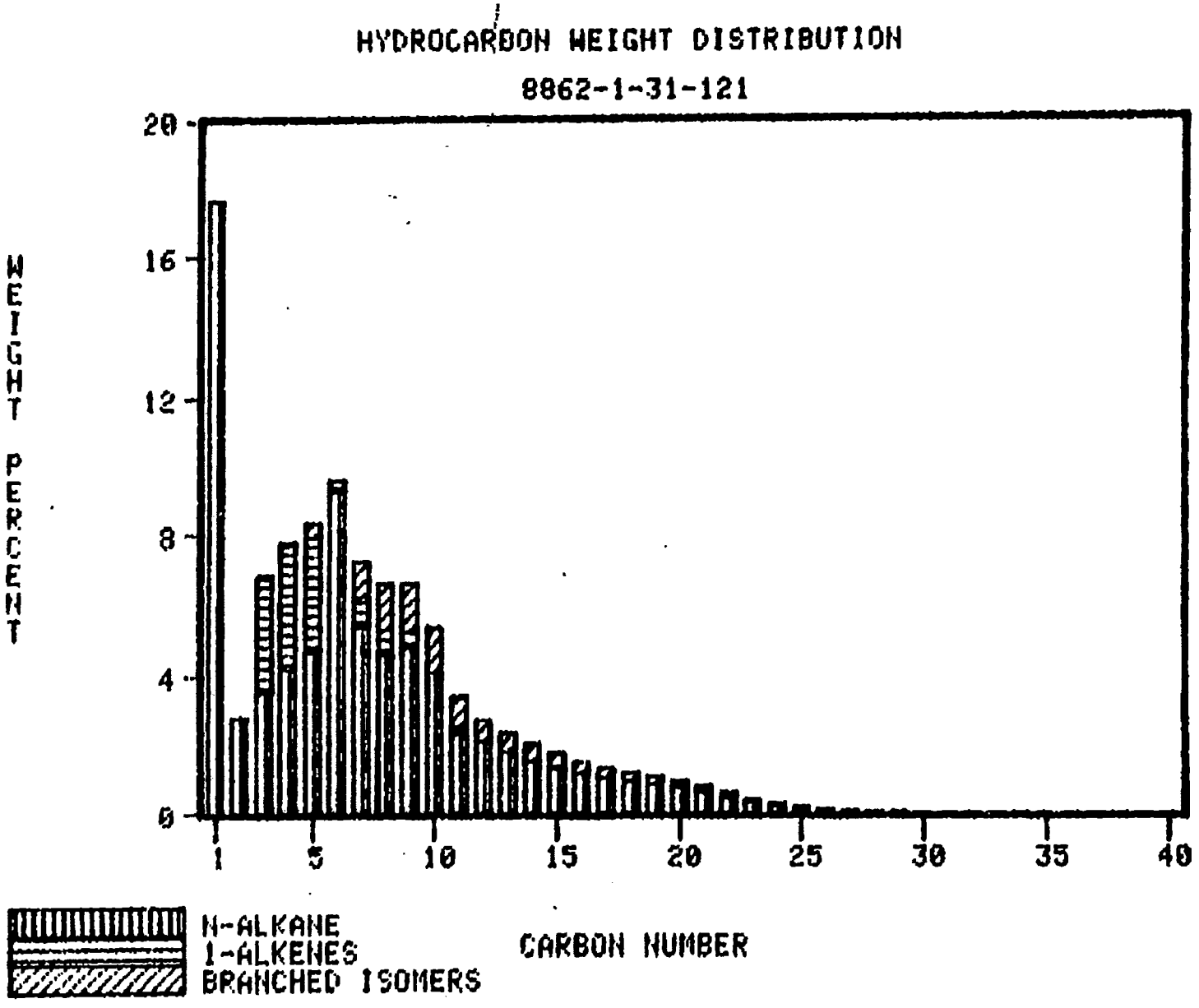

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-121
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 28

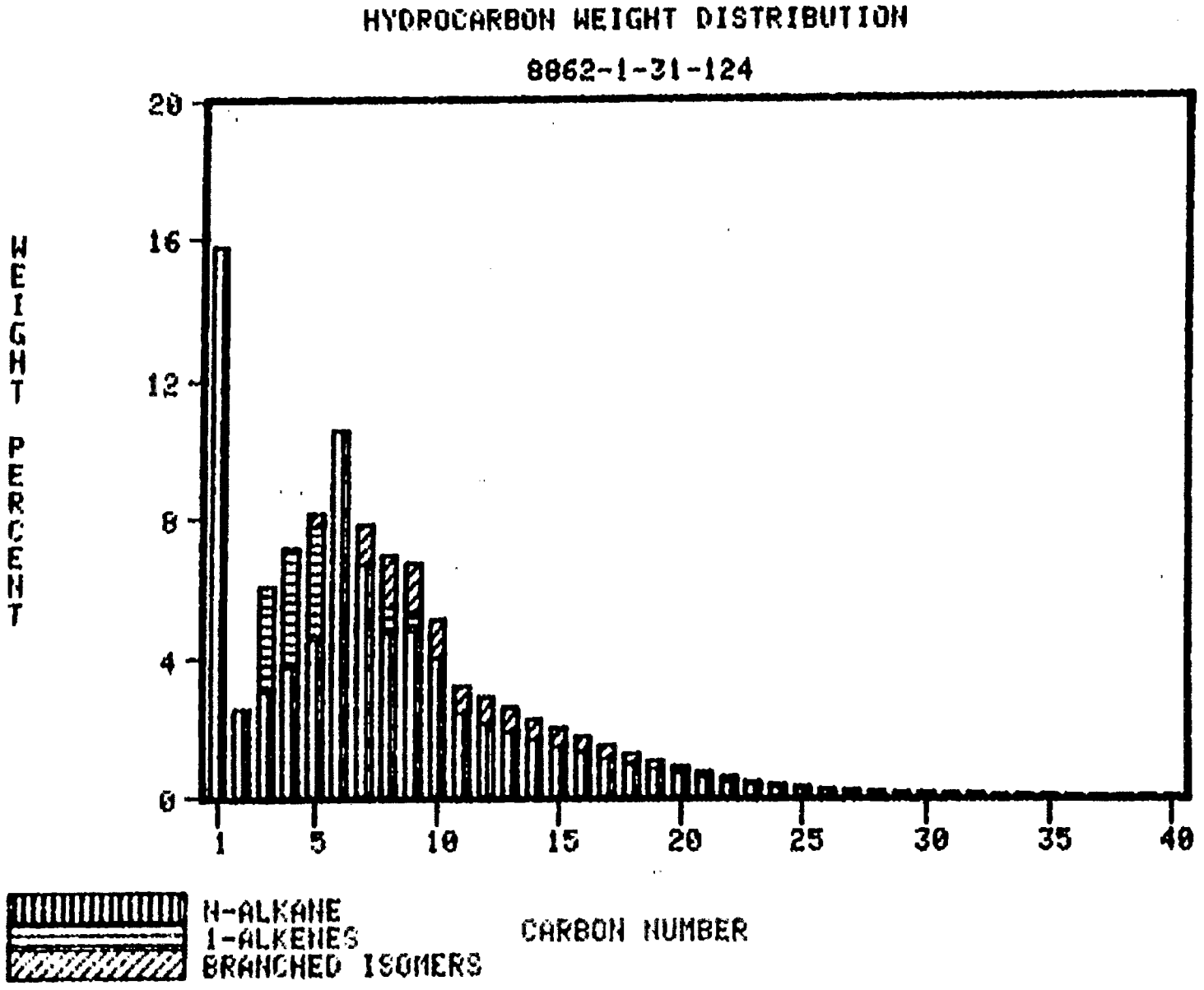

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-124
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 29

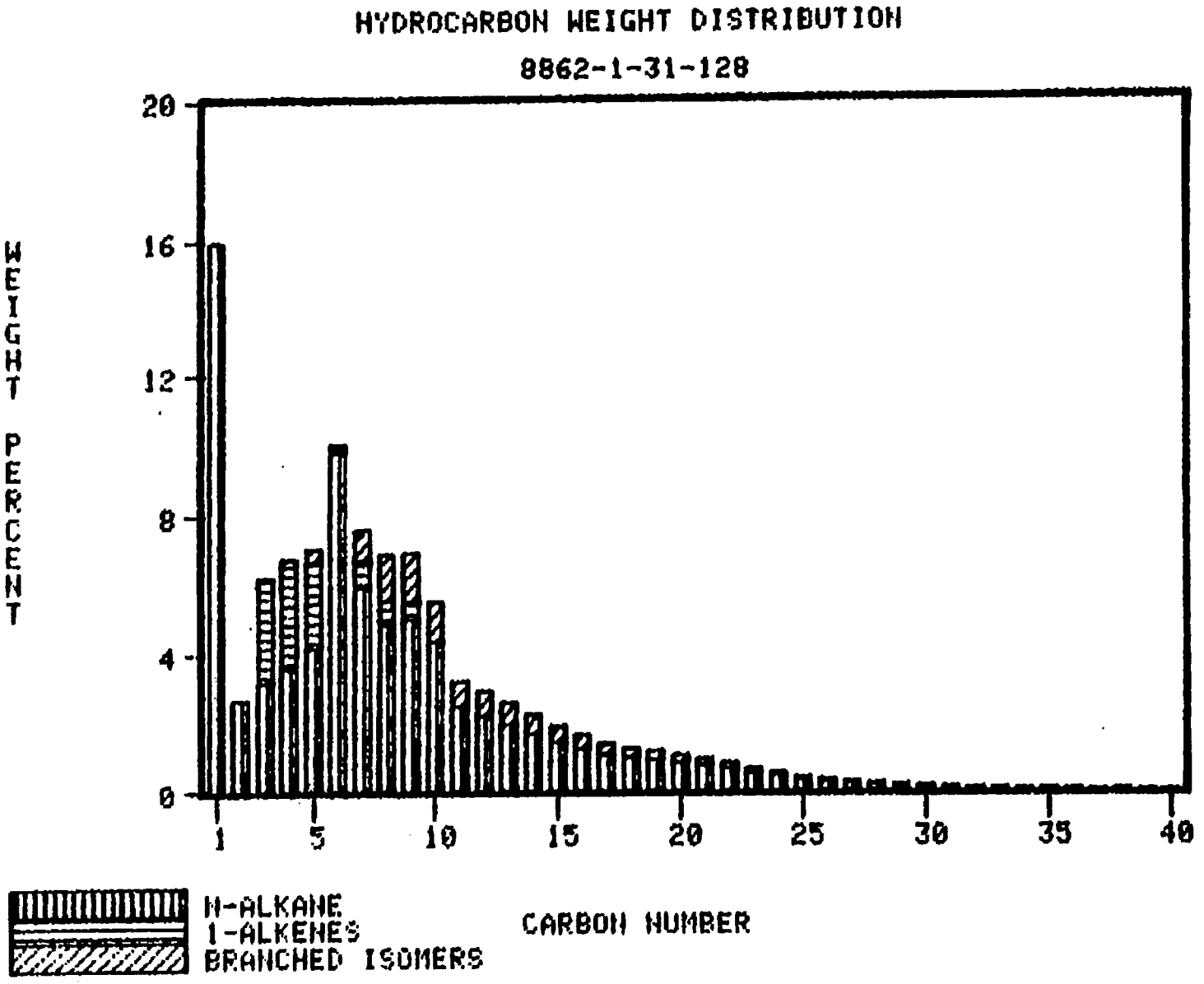

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-128
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 30

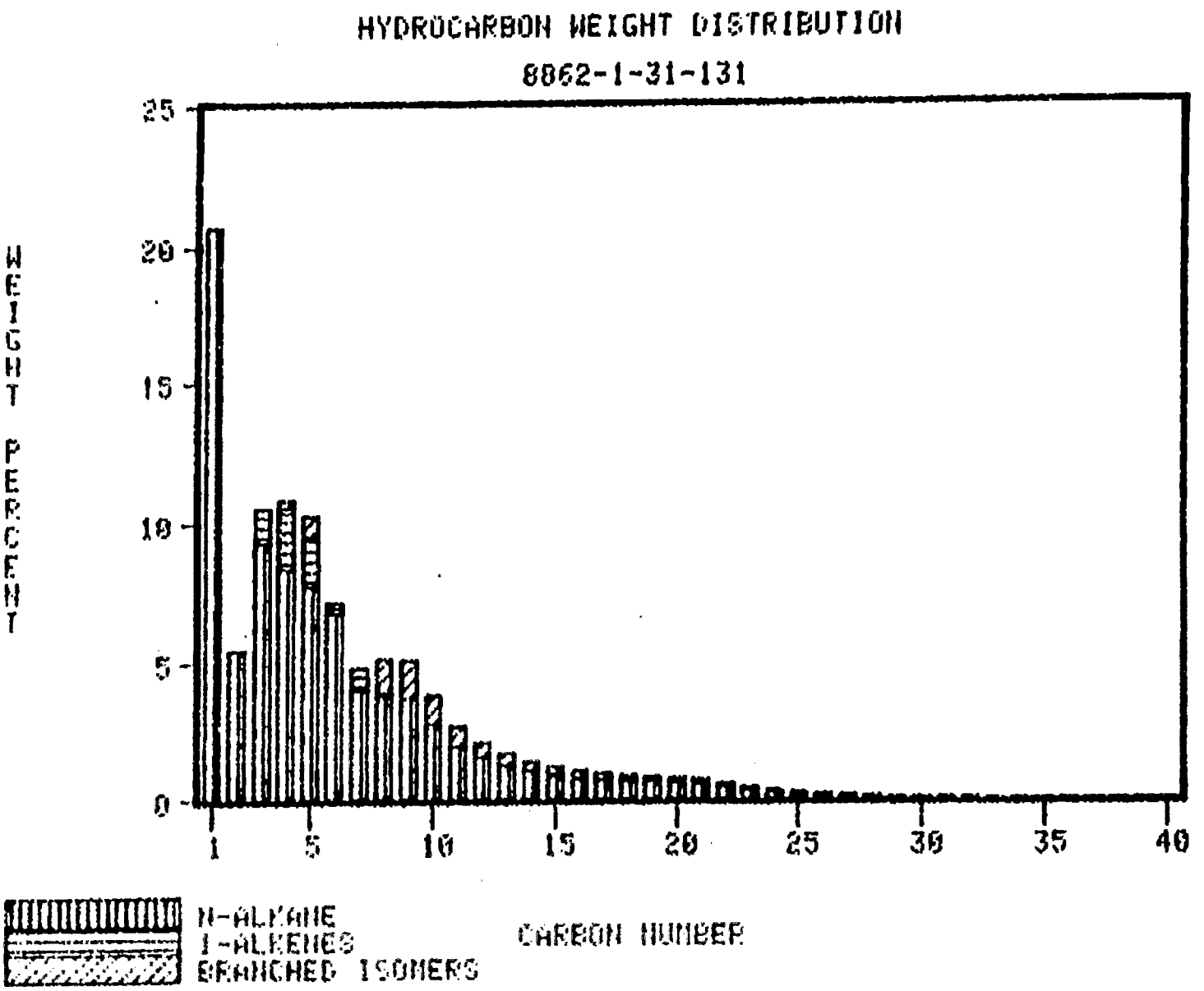

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-131
WEIGHT PERCENT
25
20
15
10
5
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 31

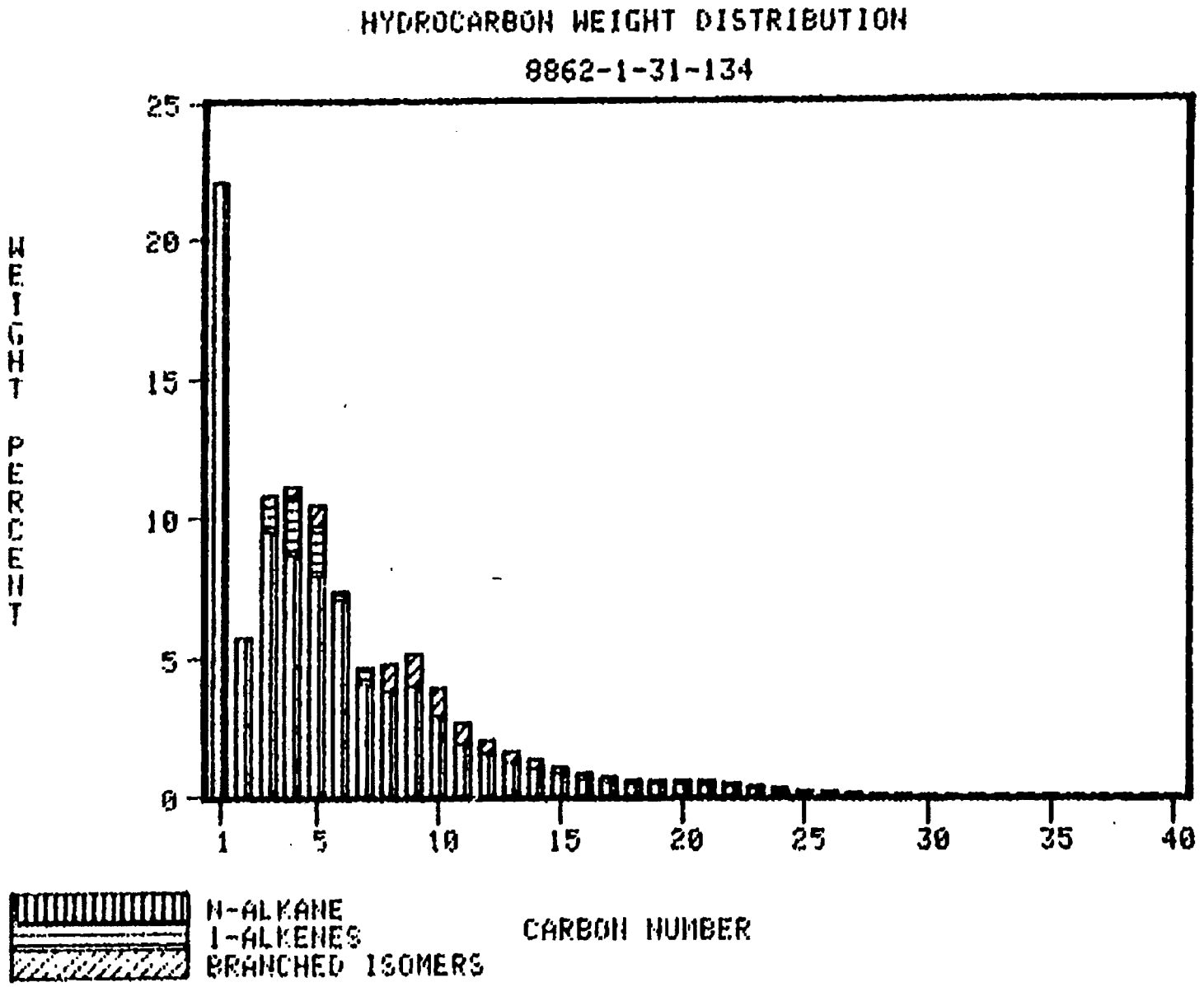

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-134
WEIGHT PERCENT
25
20
15
10
5
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 32

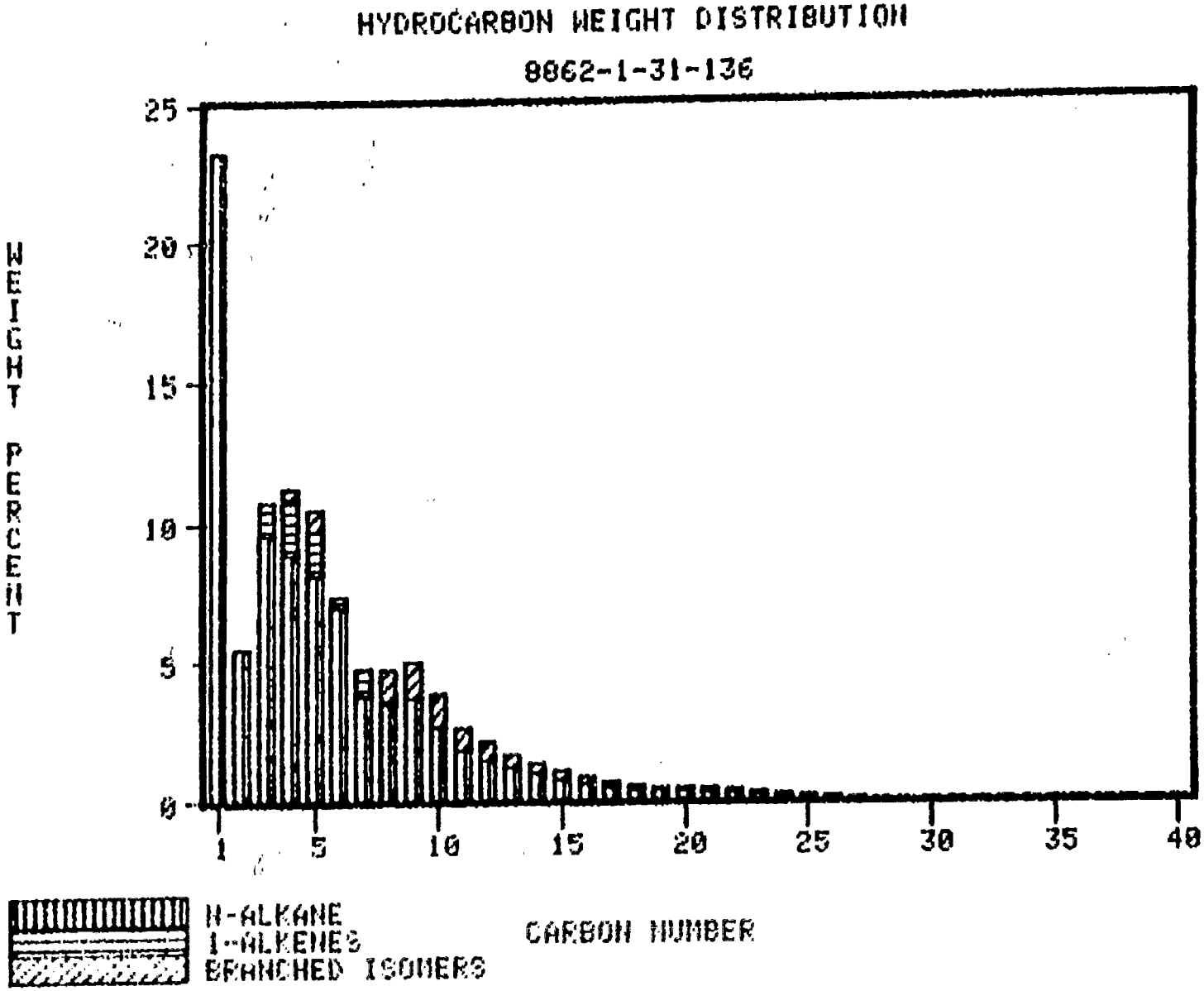

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-136
WEIGHT PERCENT
25
20
15
10
5
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 33

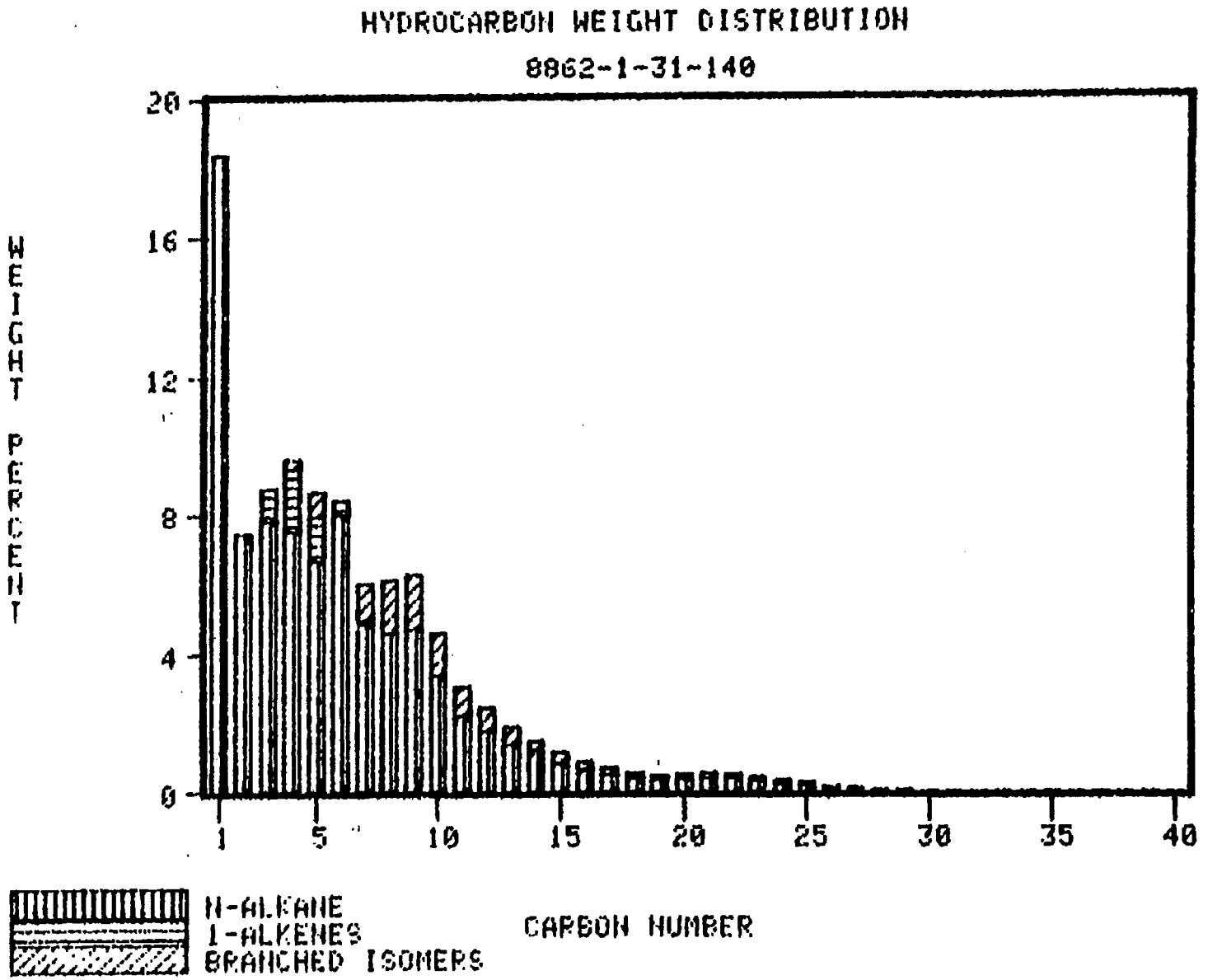

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-140
WEIGHT PERCENT
20
16
12
8
4
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 34

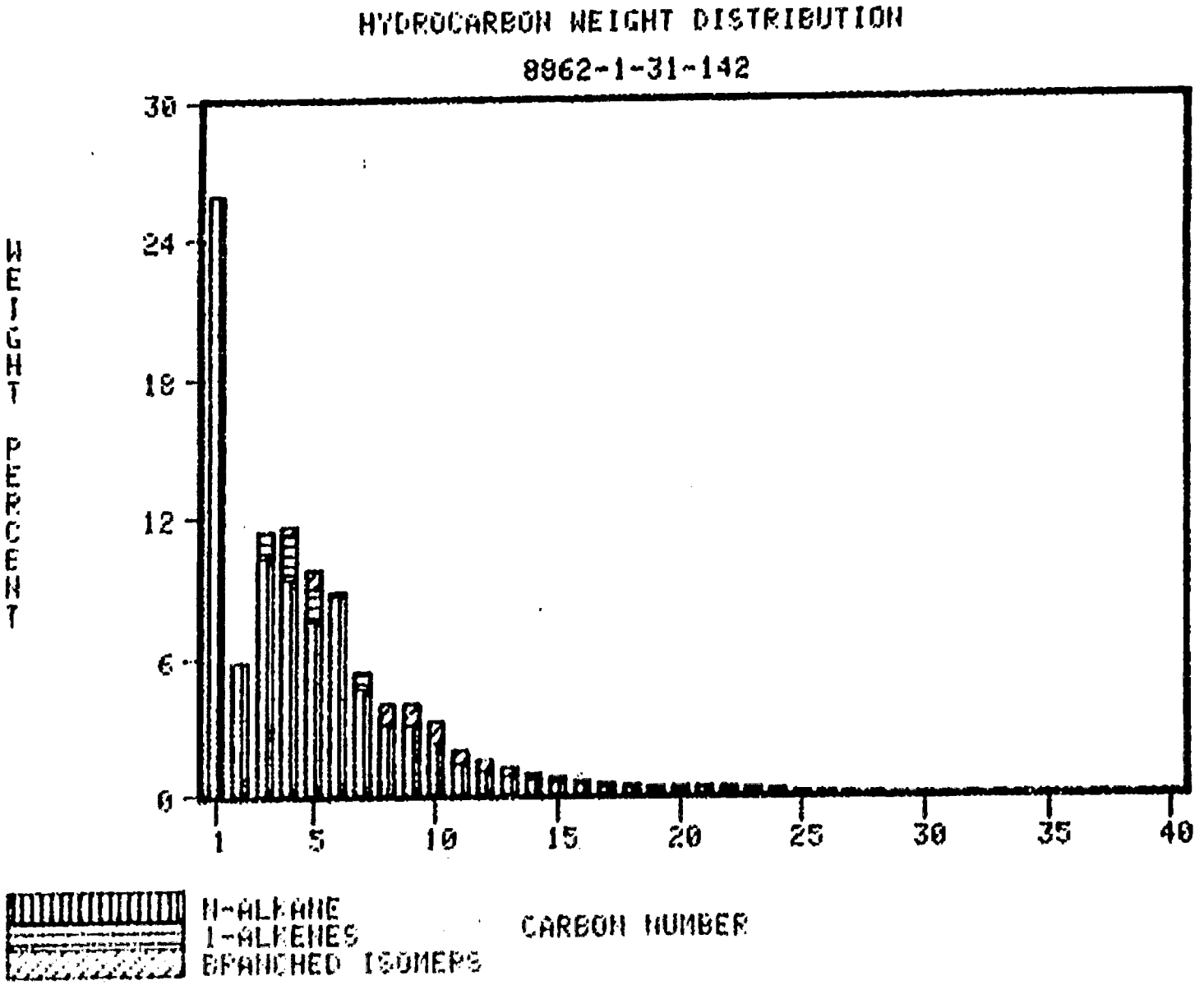

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-142
WEIGHT PERCENT
30
24
18
12
6
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 35

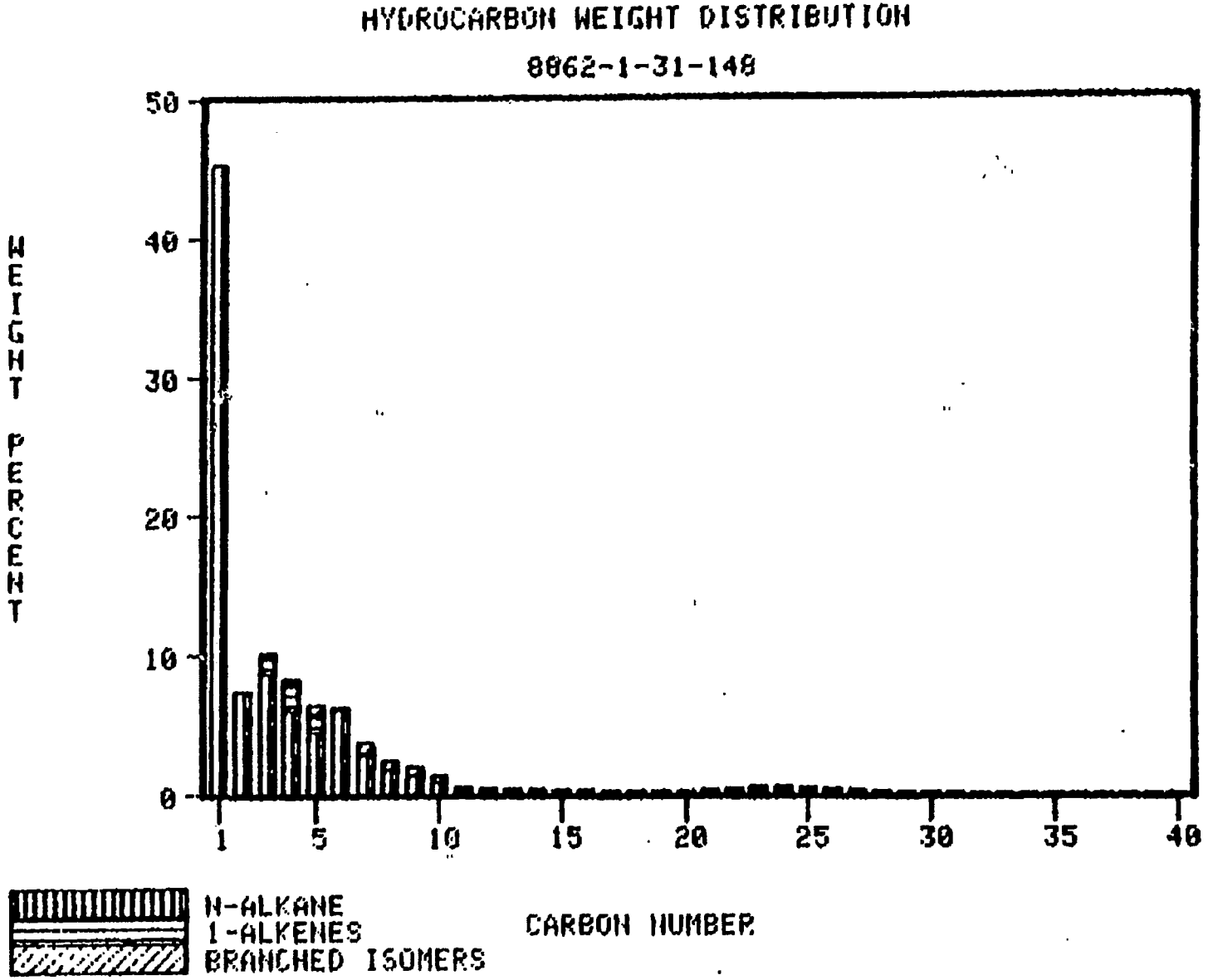

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-148
WEIGHT PERCENT
50
40
30
20
10
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 36

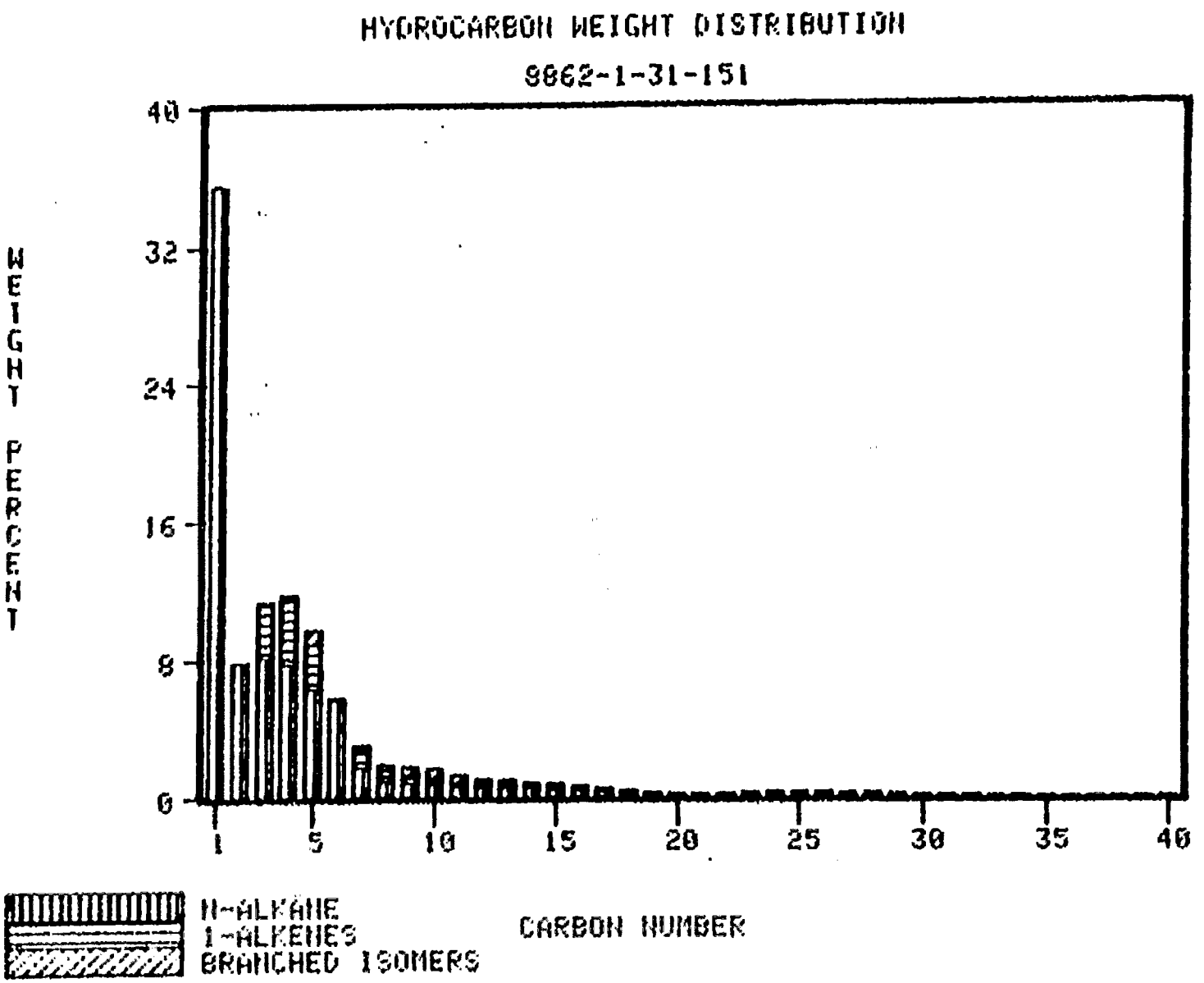

HYDROCARBON WEIGHT DISTRIBUTION
9862-1-31-151
WEIGHT PERCENT
40
32
24
16
8
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 37

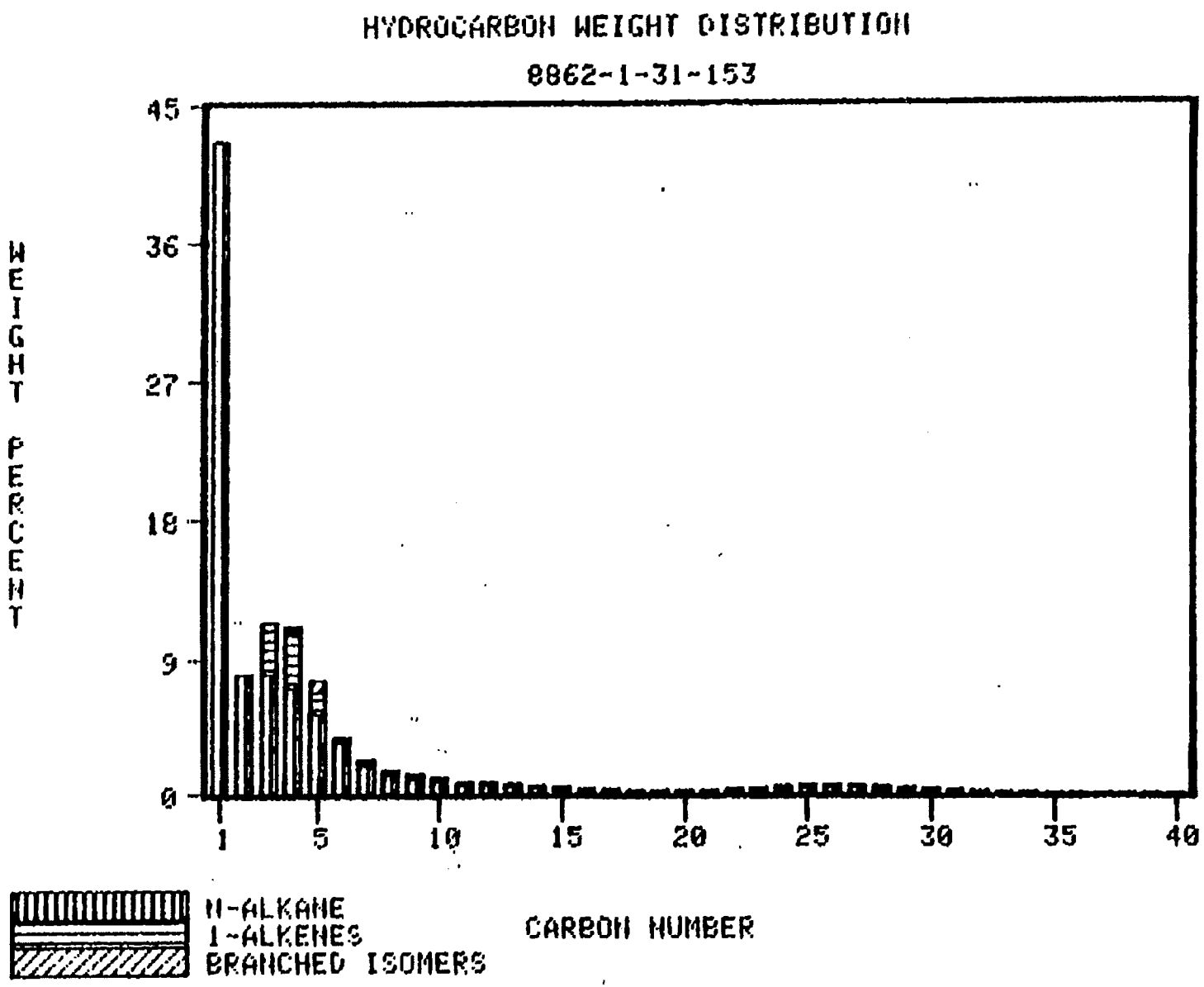

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-153
WEIGHT PERCENT
45
36
27
18
9
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 38

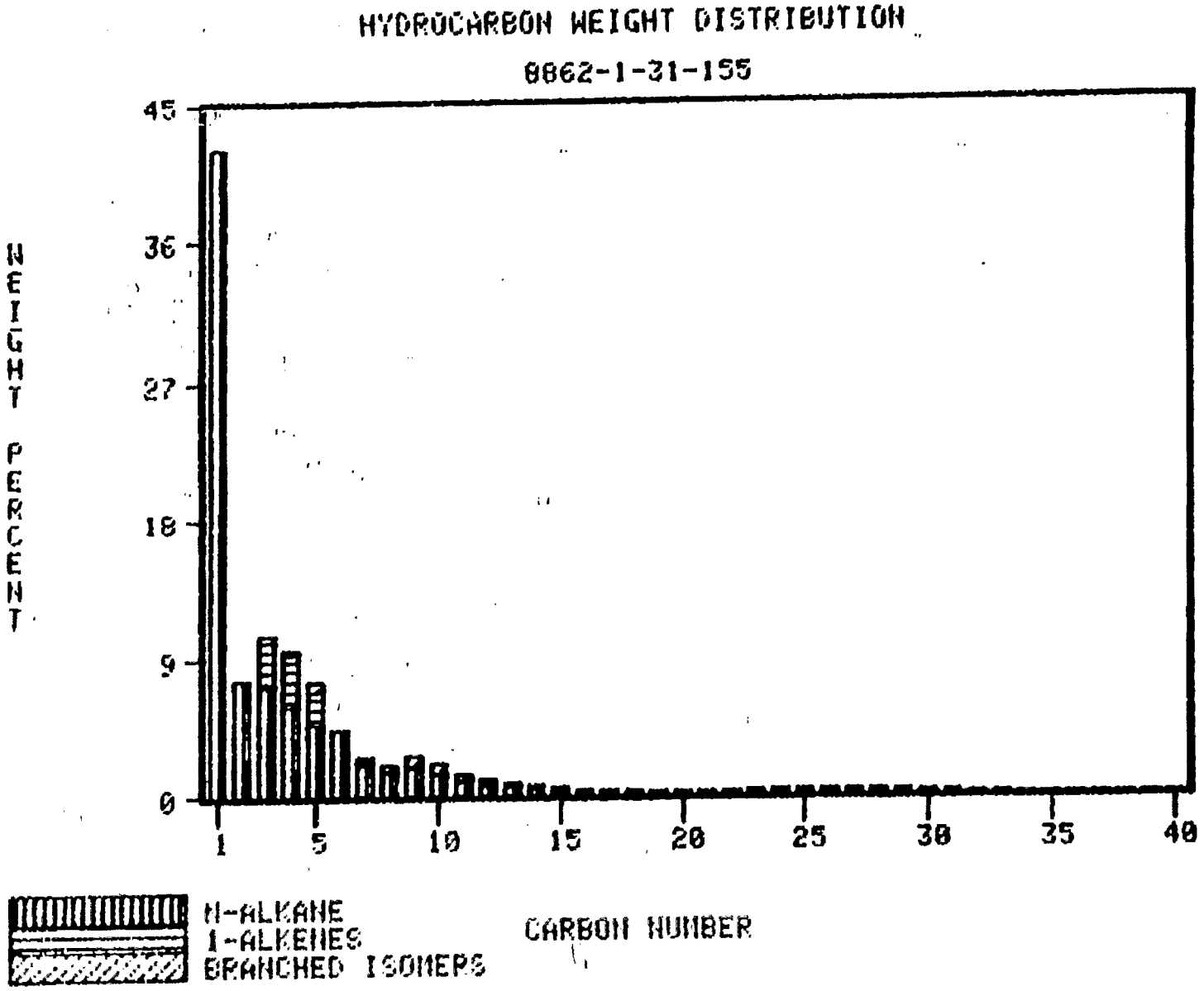

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-155
WEIGHT PERCENT
45
36
27
18
9
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 39

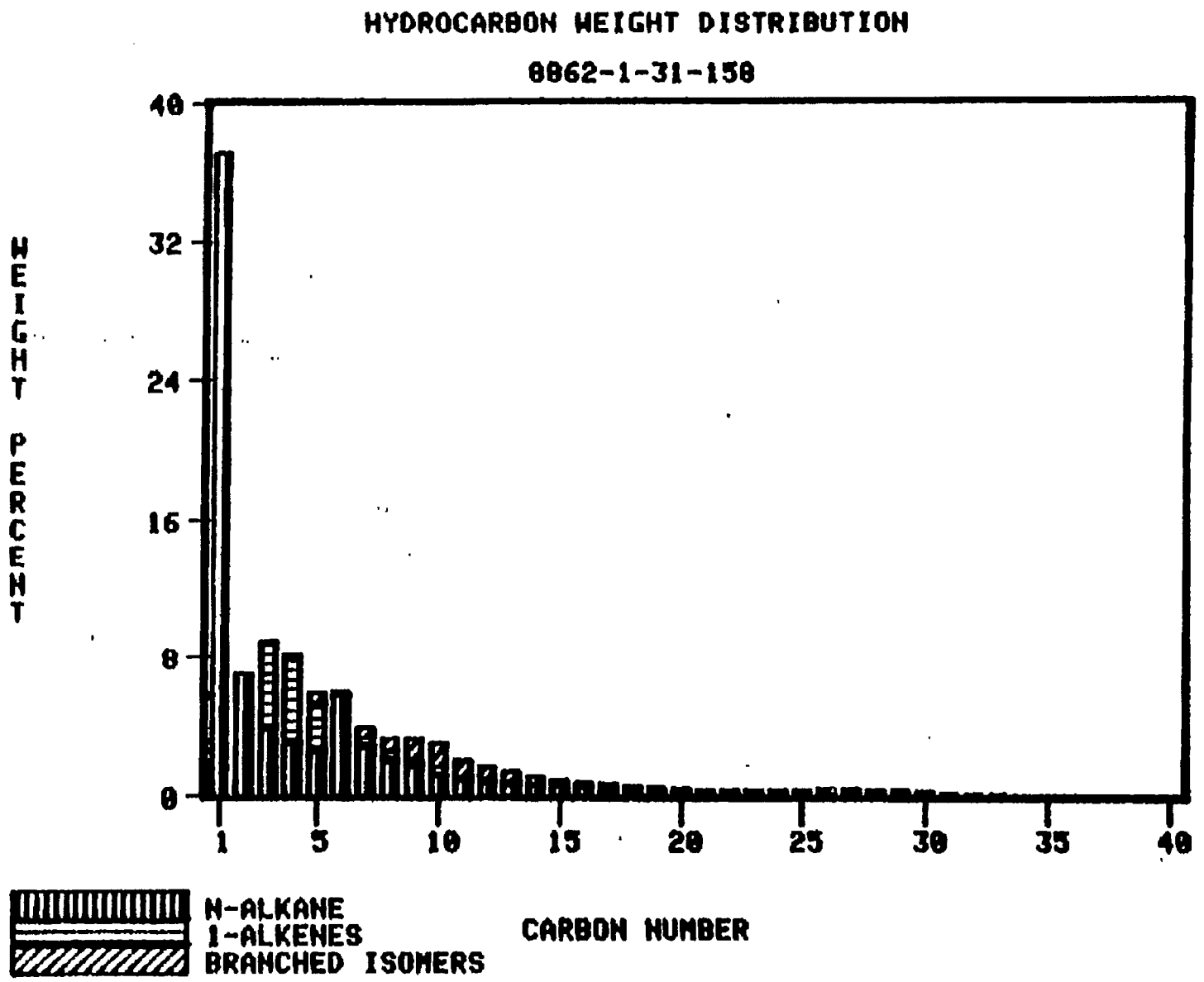

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-158
WEIGHT PERCENT
40
32
24
16
8
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 40

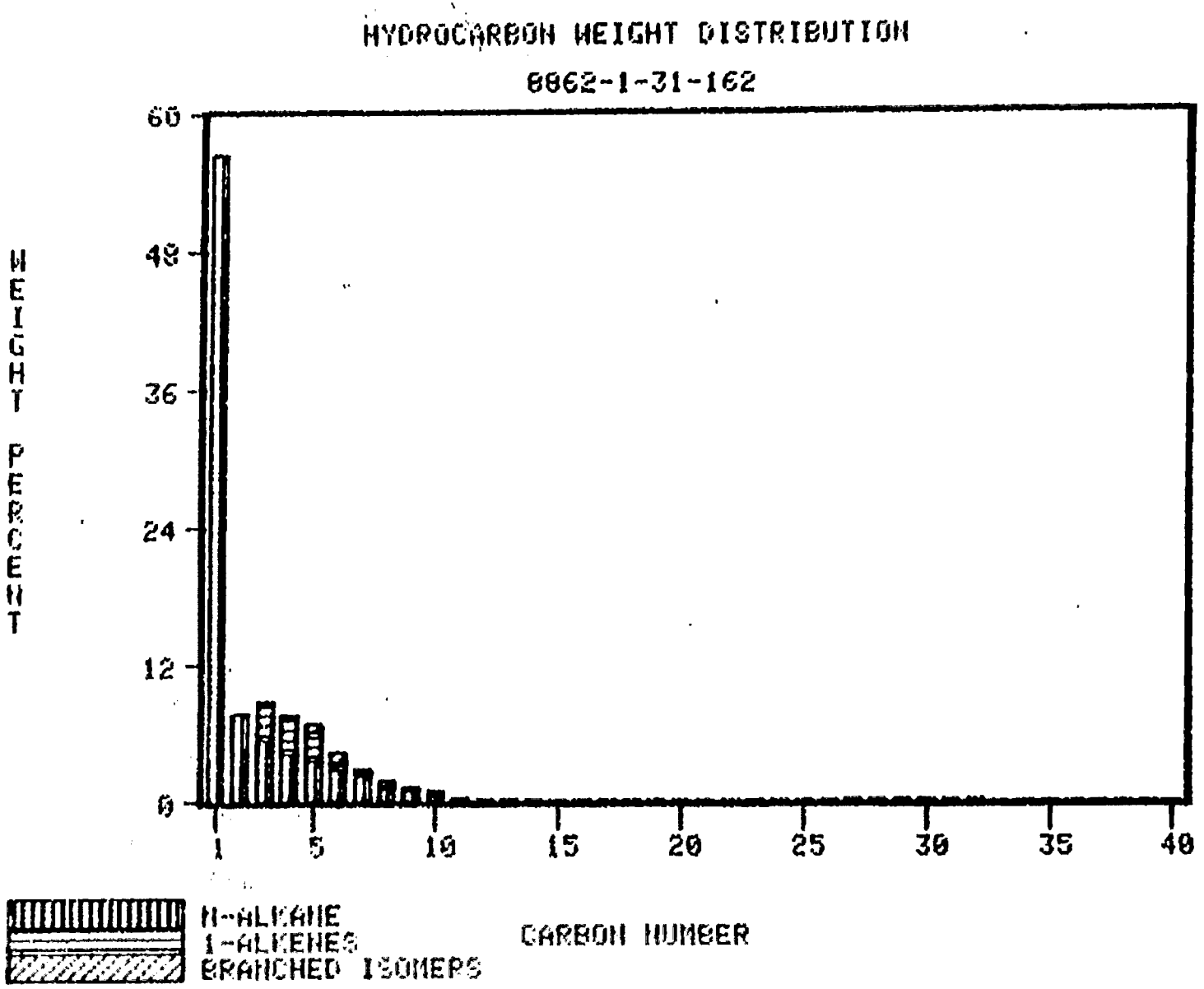

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-162
WEIGHT PERCENT
60
48
36
24
12
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 41

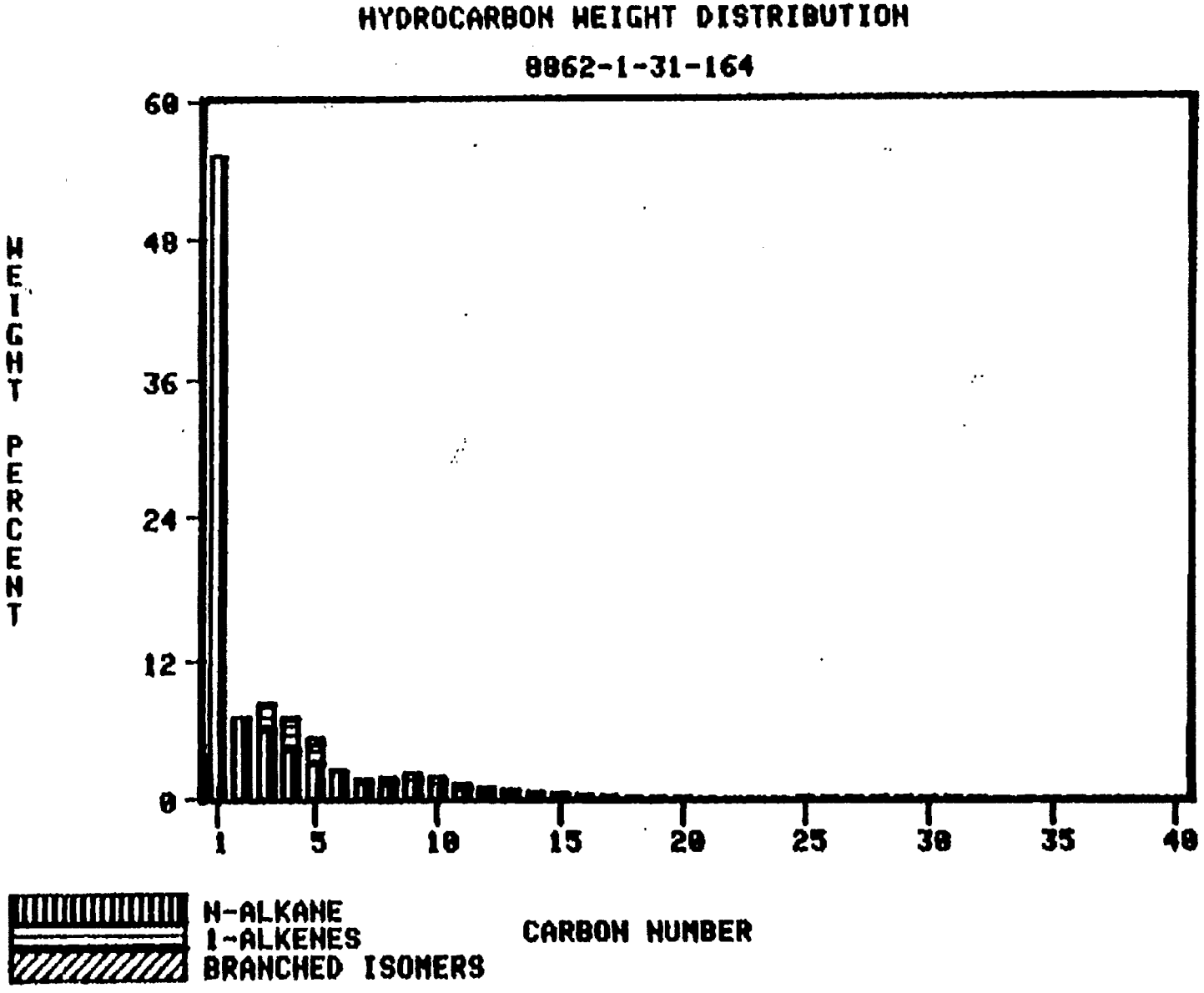

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-164
WEIGHT PERCENT
60
48
36
24
12
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 42

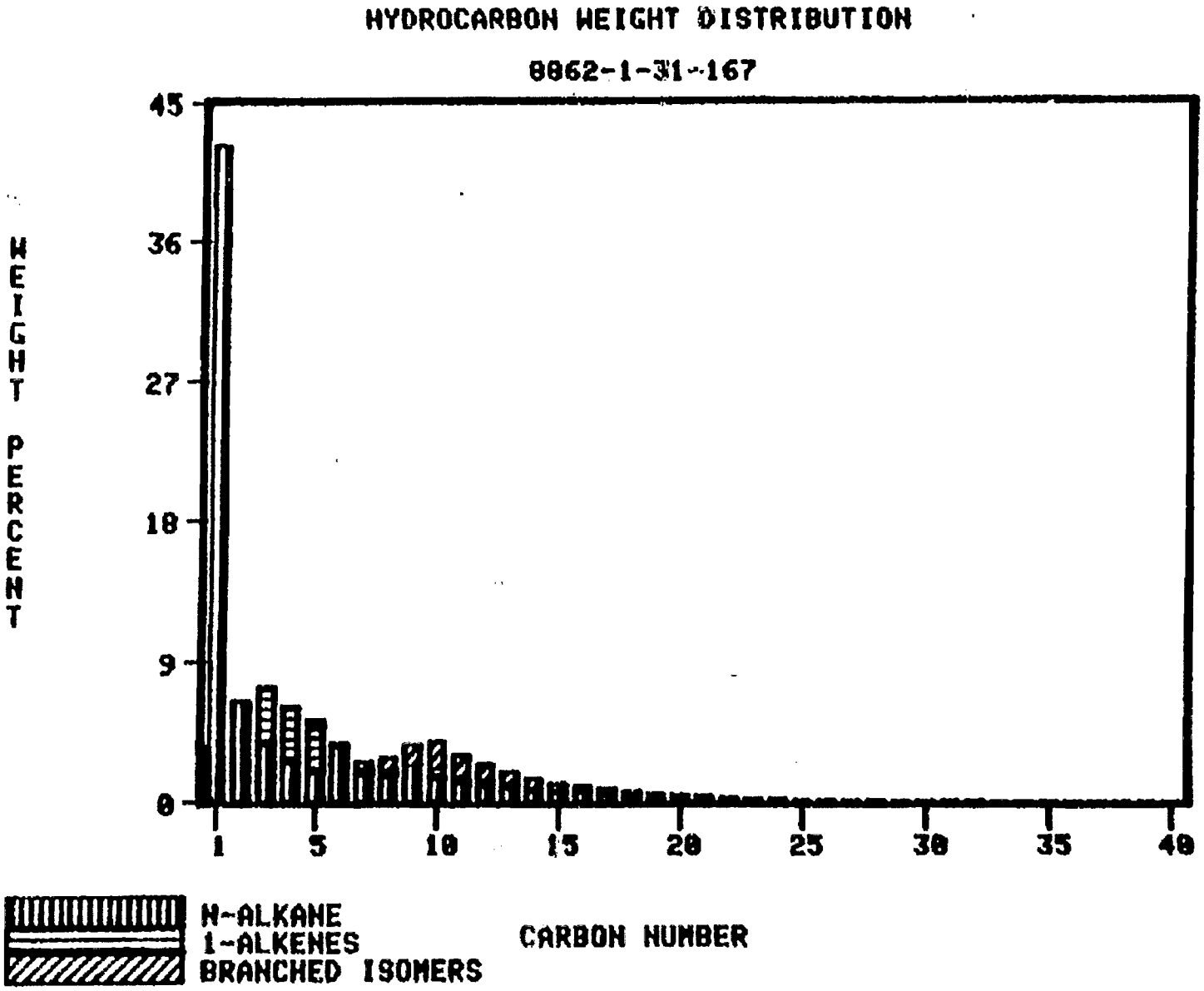

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-167
WEIGHT PERCENT
45
36
27
18
9
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 43

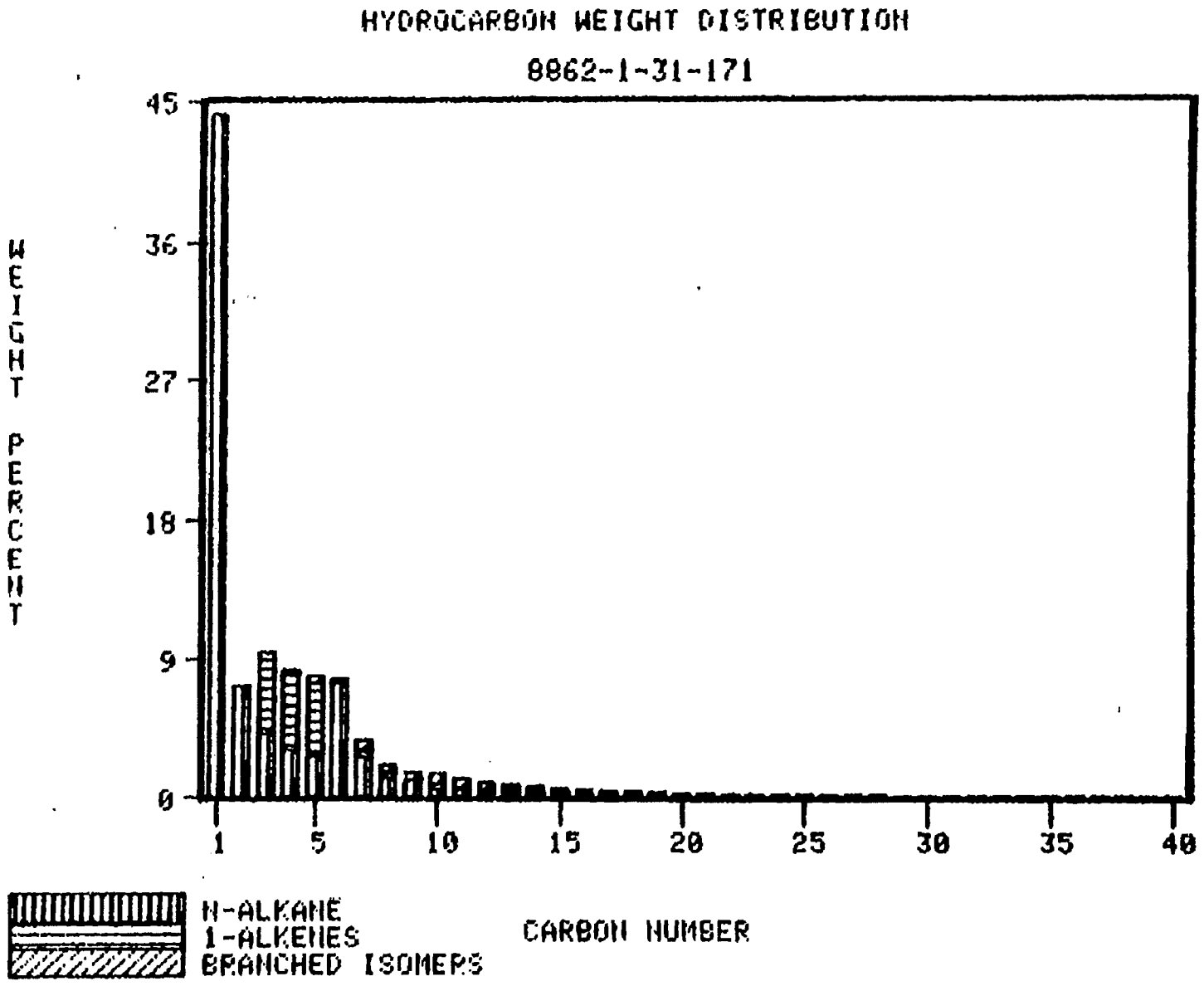

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-171
WEIGHT PERCENT
45
36
27
18
9
0
1
5
10
15
20
25
30
35
40
N-ALKANE
1-ALKENES
BRANCHED ISOMERS
CARBON NUMBER

FIGURE 44

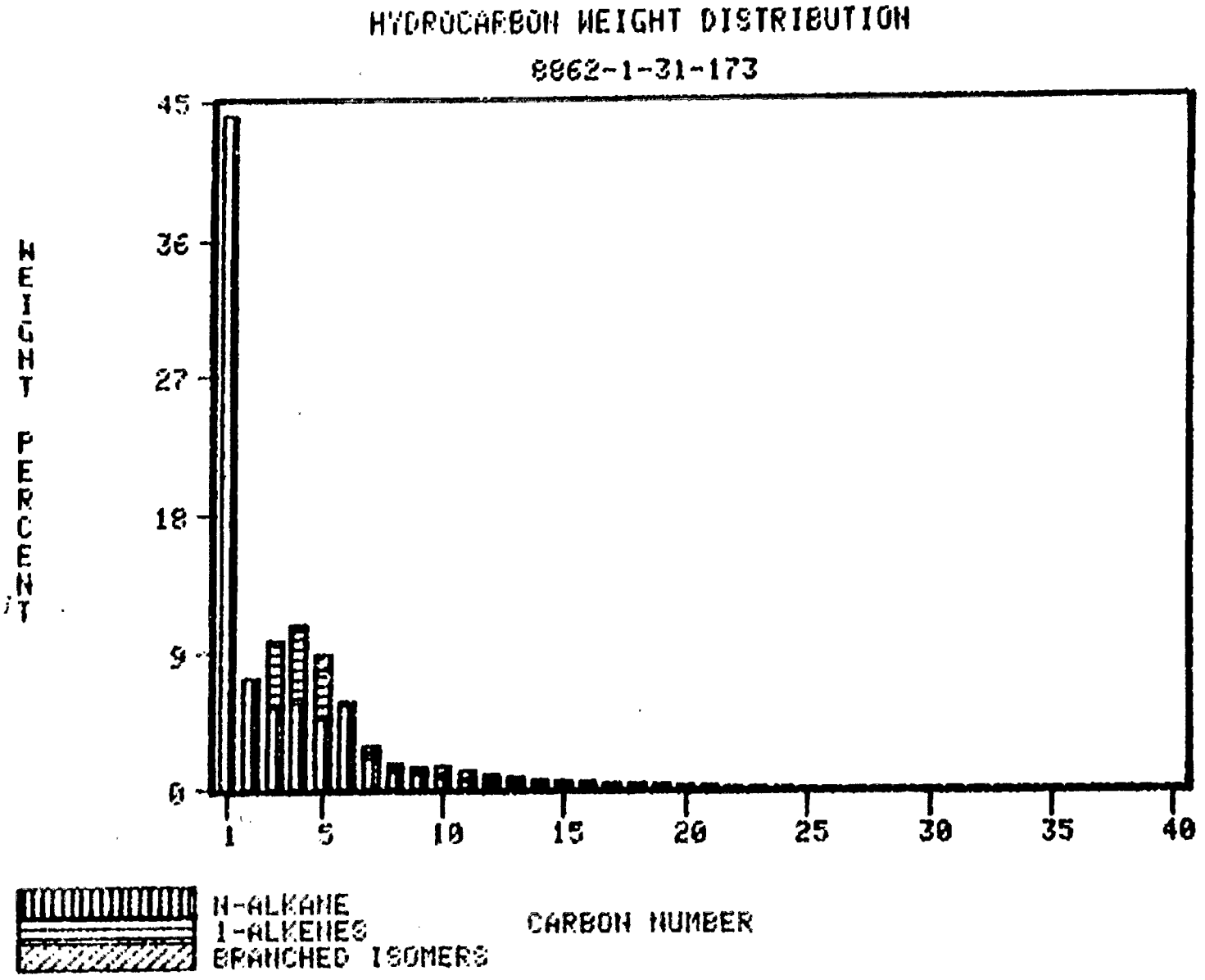

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-173
WEIGHT PERCENT
45
36
27
18
9
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 45

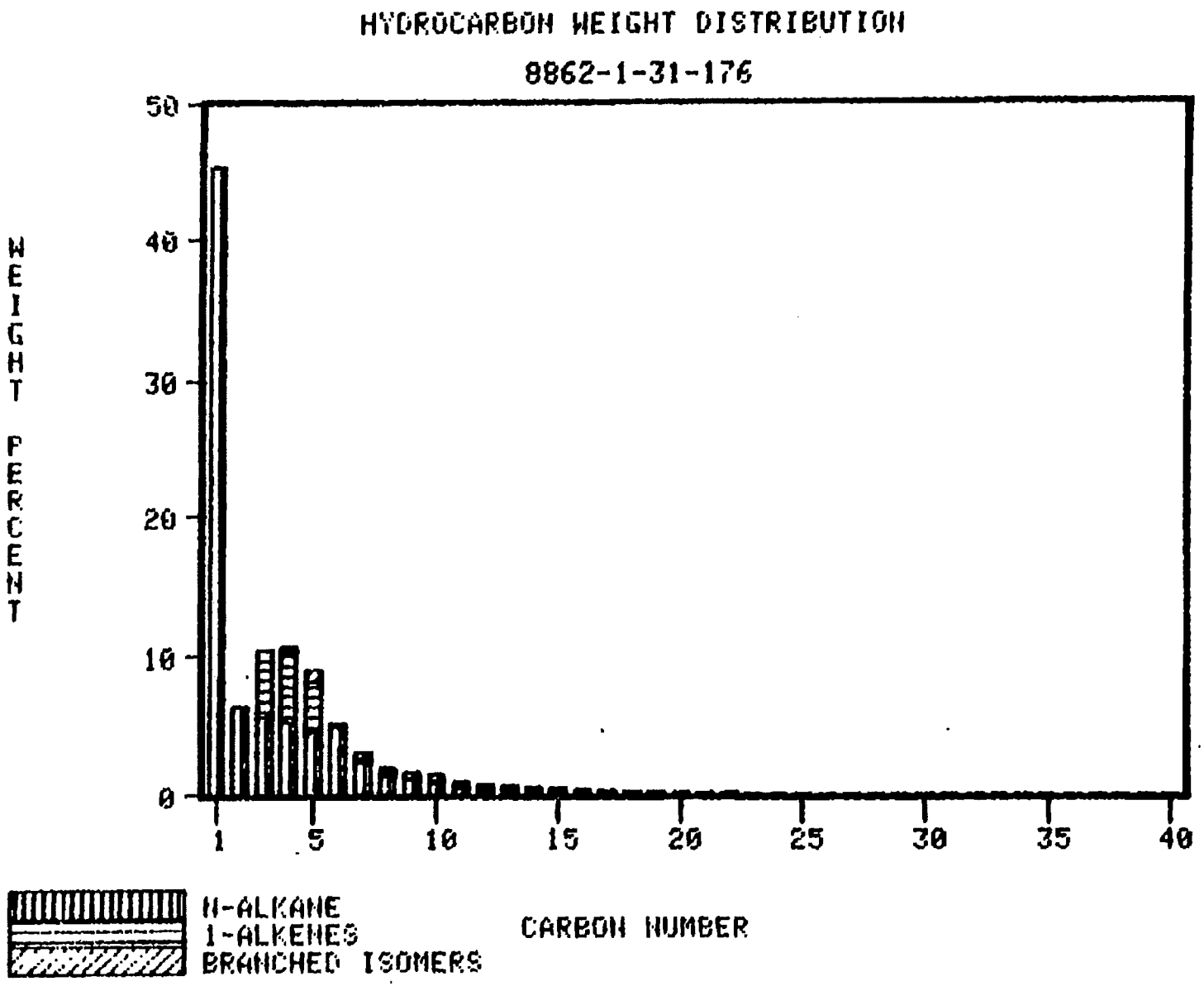

HYDROCARBON WEIGHT DISTRIBUTION
8862-1-31-176
WEIGHT PERCENT
50
40
30
20
10
0
1
5
10
15
20
25
30
35
40
CARBON NUMBER
N-ALKANE
1-ALKENES
BRANCHED ISOMERS

FIGURE 46

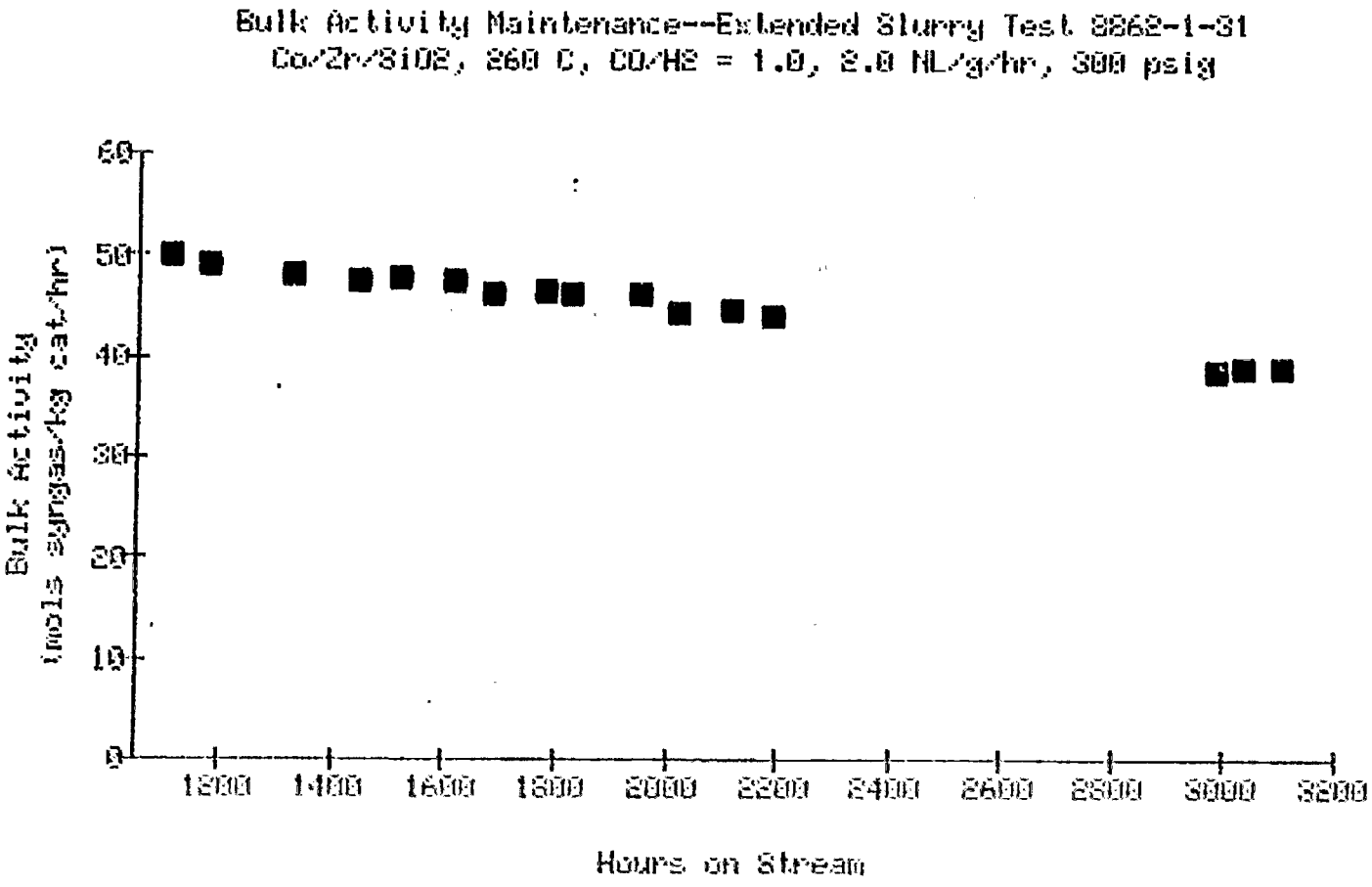

Bulk Activity Maintenance--Extended Slurry Test 8862-1-31
Co/2r/SiO2, 260 C, CO/H2 = 1.0, 2.0 NL/g/hr, 300 psig
Bulk Activity
(mols syngas/kg cat/hr)
60
50
40
30
20
10
0
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
Hours on Stream

FIGURE 47

Linear Fit for Kinetic Model 1

Temperature = 260°C

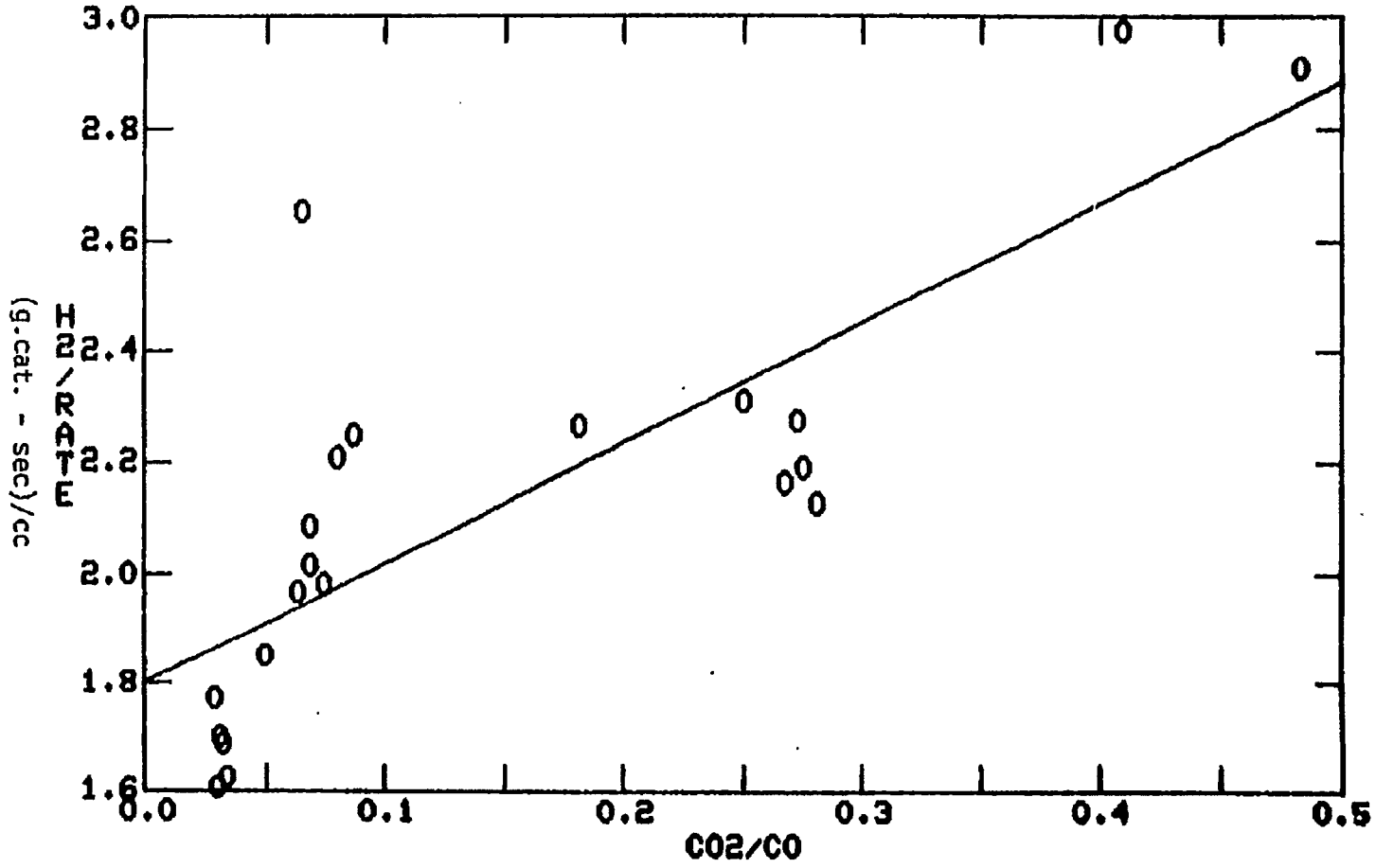


FIGURE 48

Linear Fit for Kinetic Model 2

Temperature = 260°C

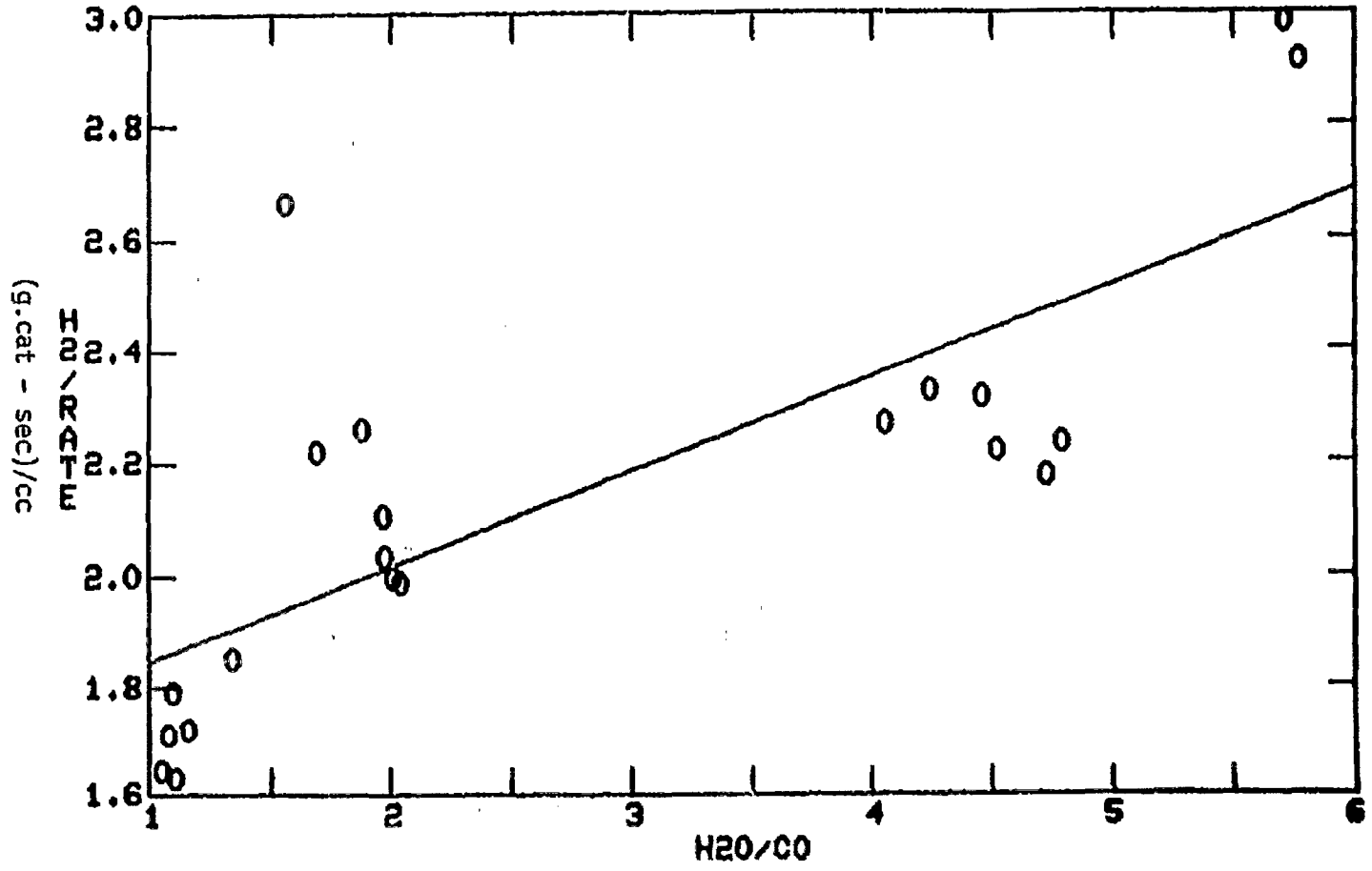


FIGURE 49

Linear Fit for Kinetic Model 4

Temperature = 260^{0}C

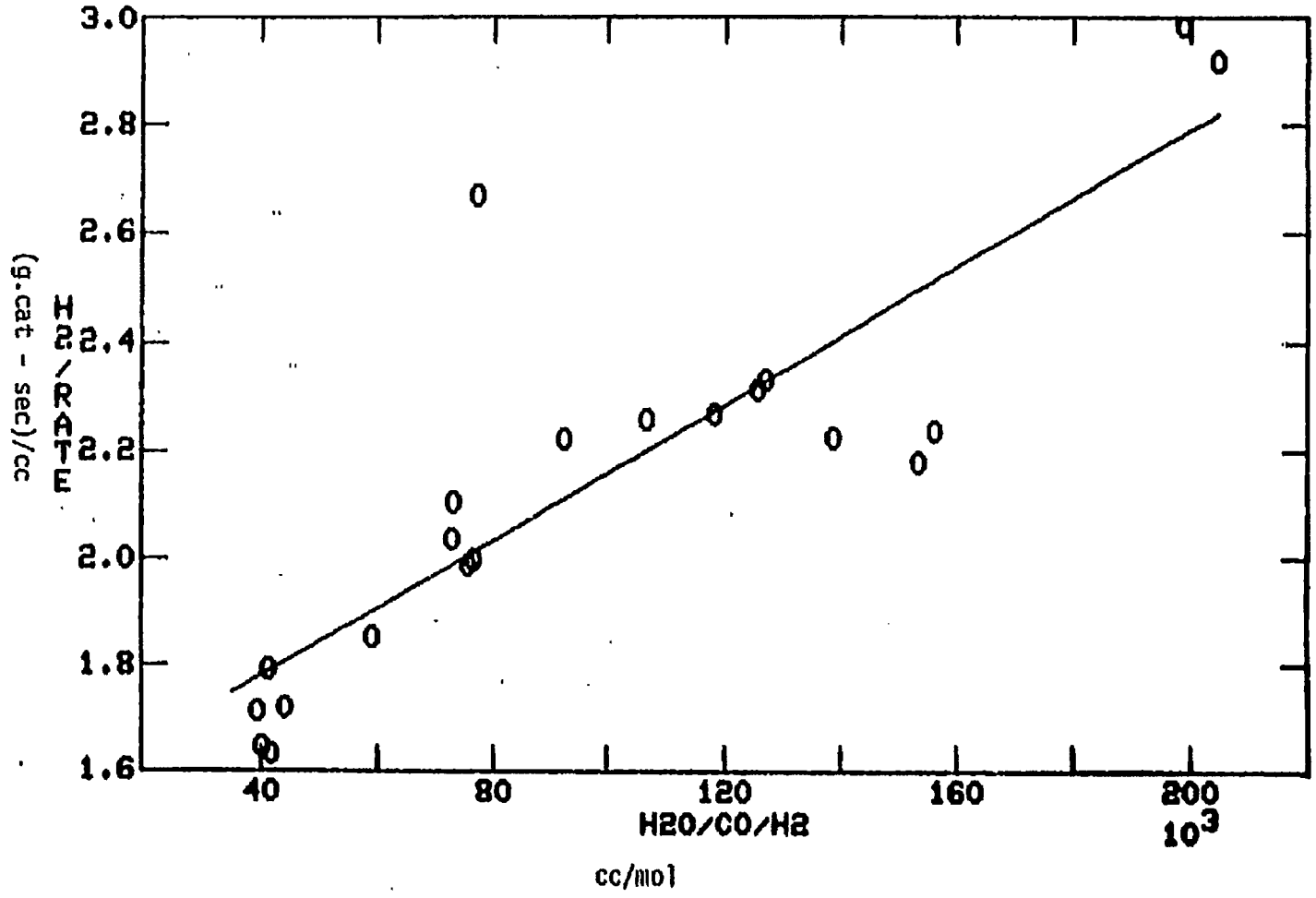


FIGURE 50

Parity Plot for Kinetic Model 1

Temperature = 260°C

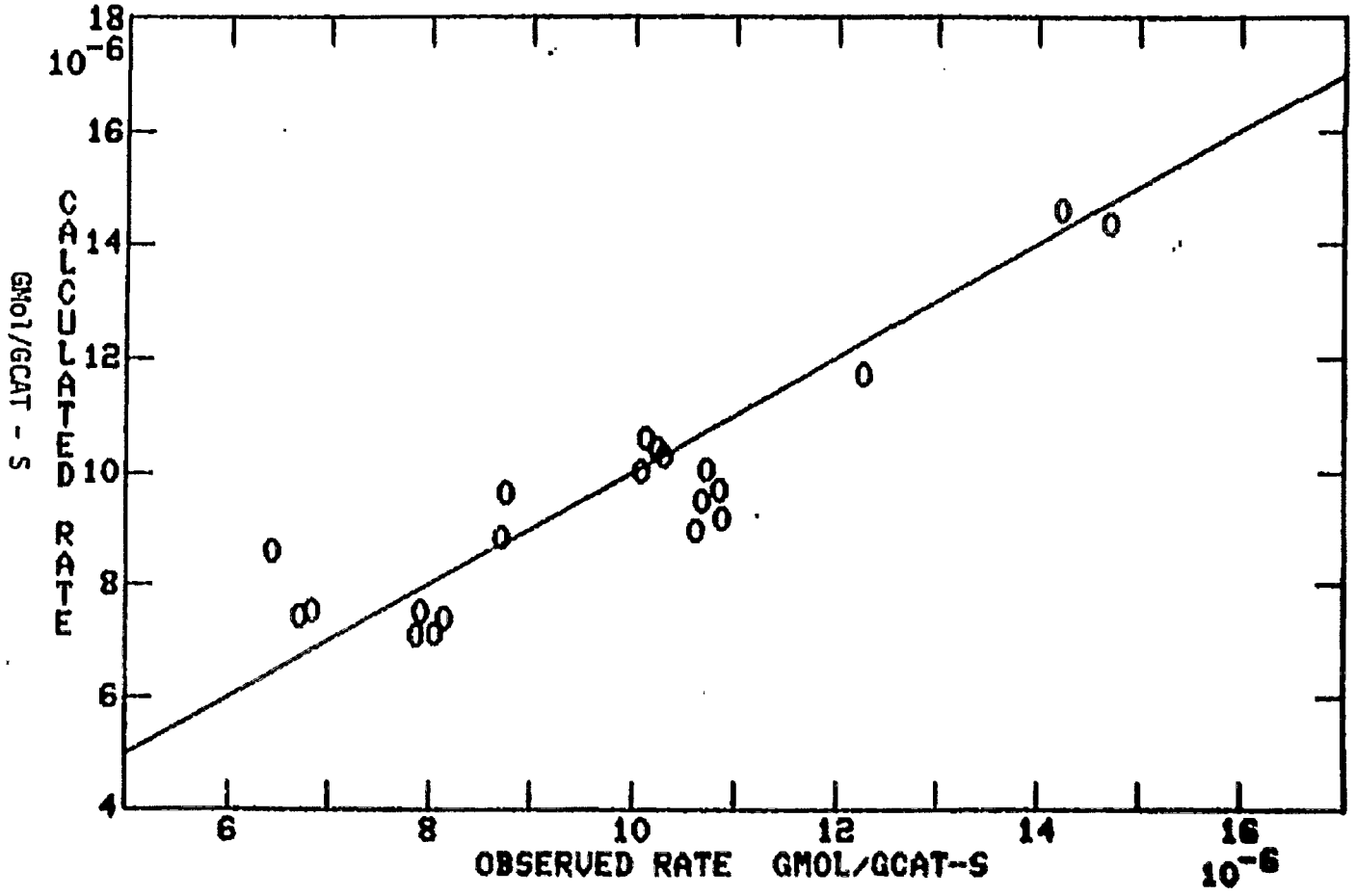


FIGURE 51

Parity Plot for Kinetic Model 2

Temperature 260°C

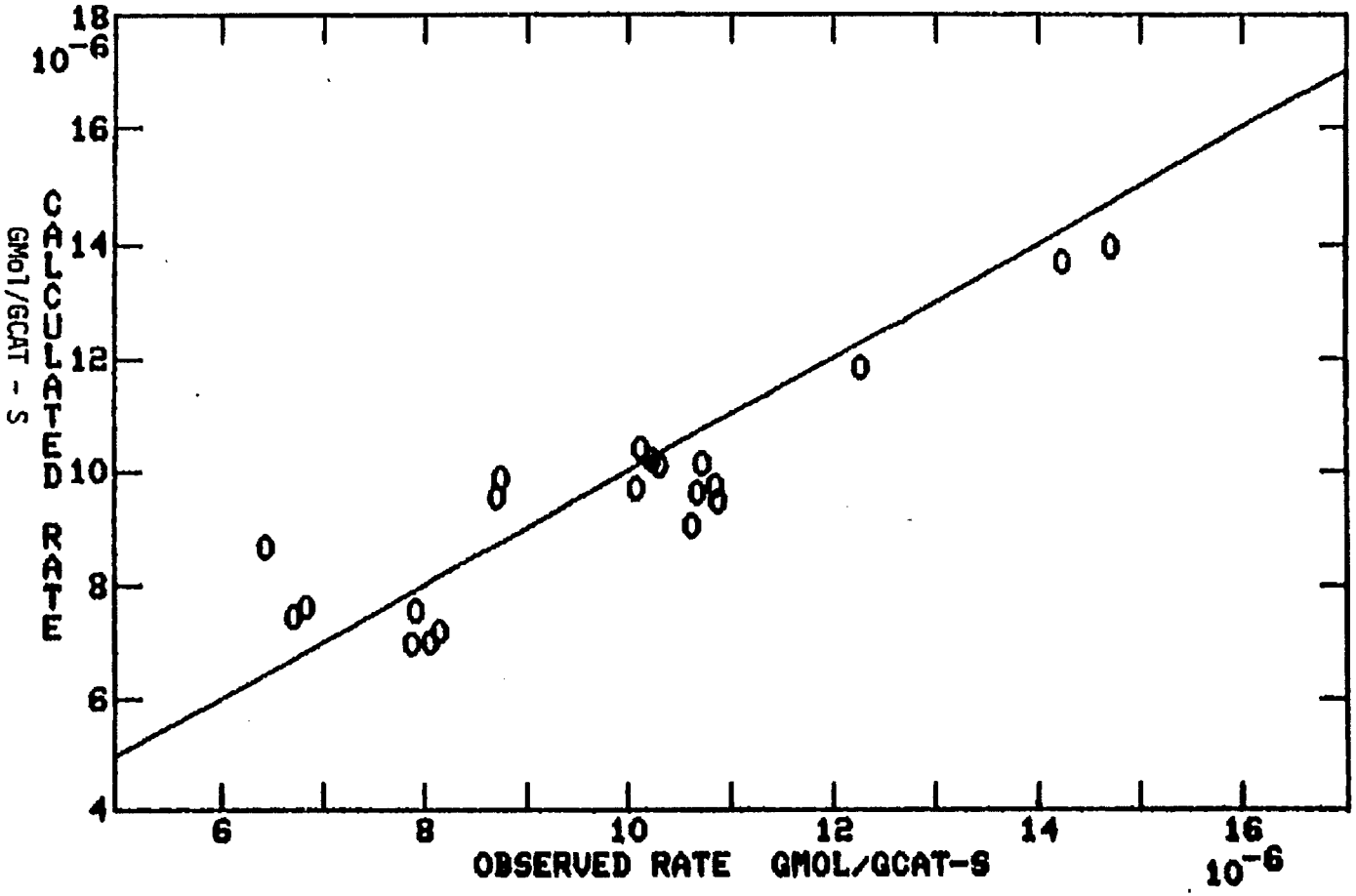


FIGURE 52

Parity Plot for Kinetic Model 4

Temperature = 260°C

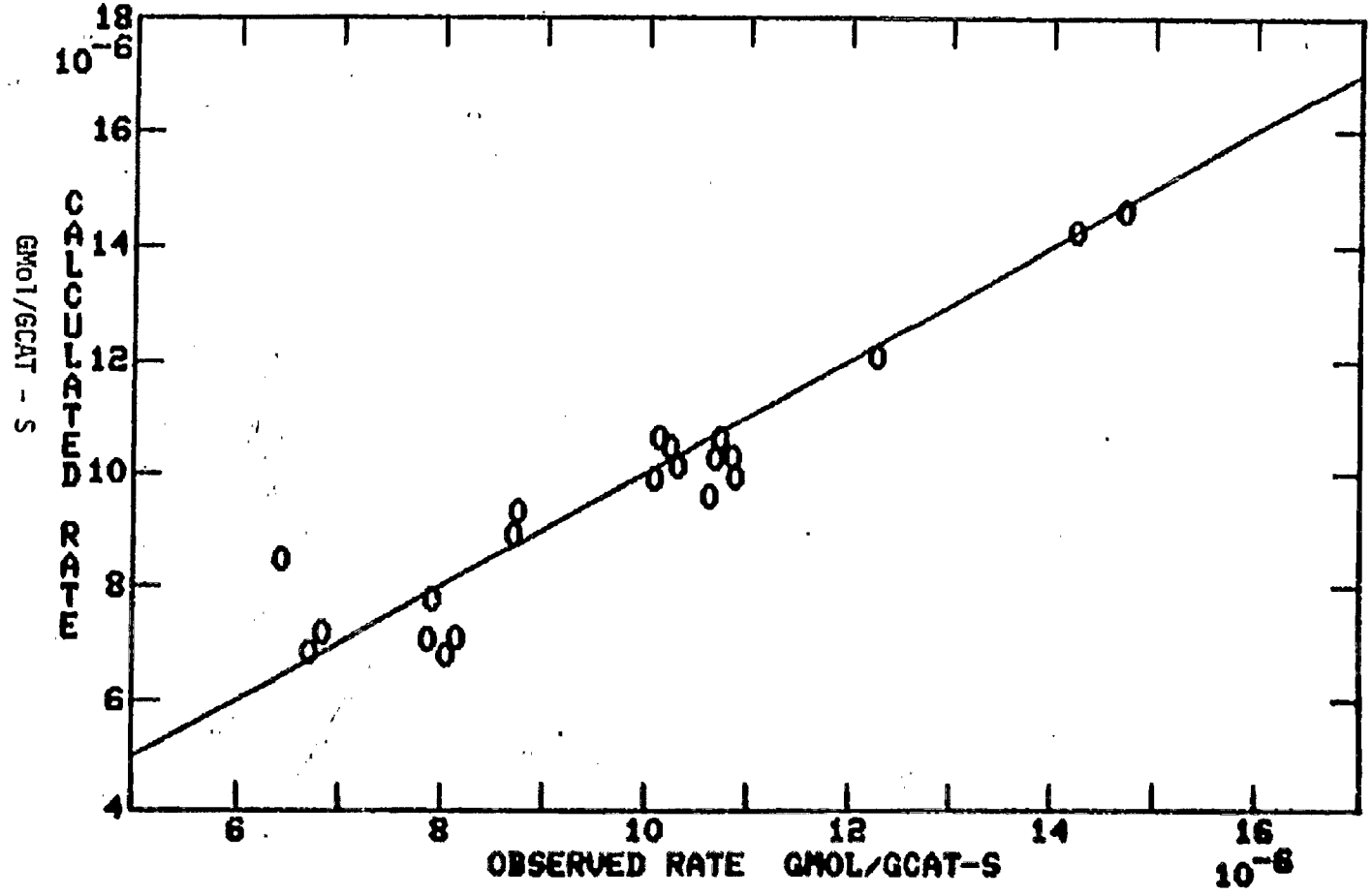


FIGURE 53

Parity Plot for Kinetic Model 5

Temperature = 260°C

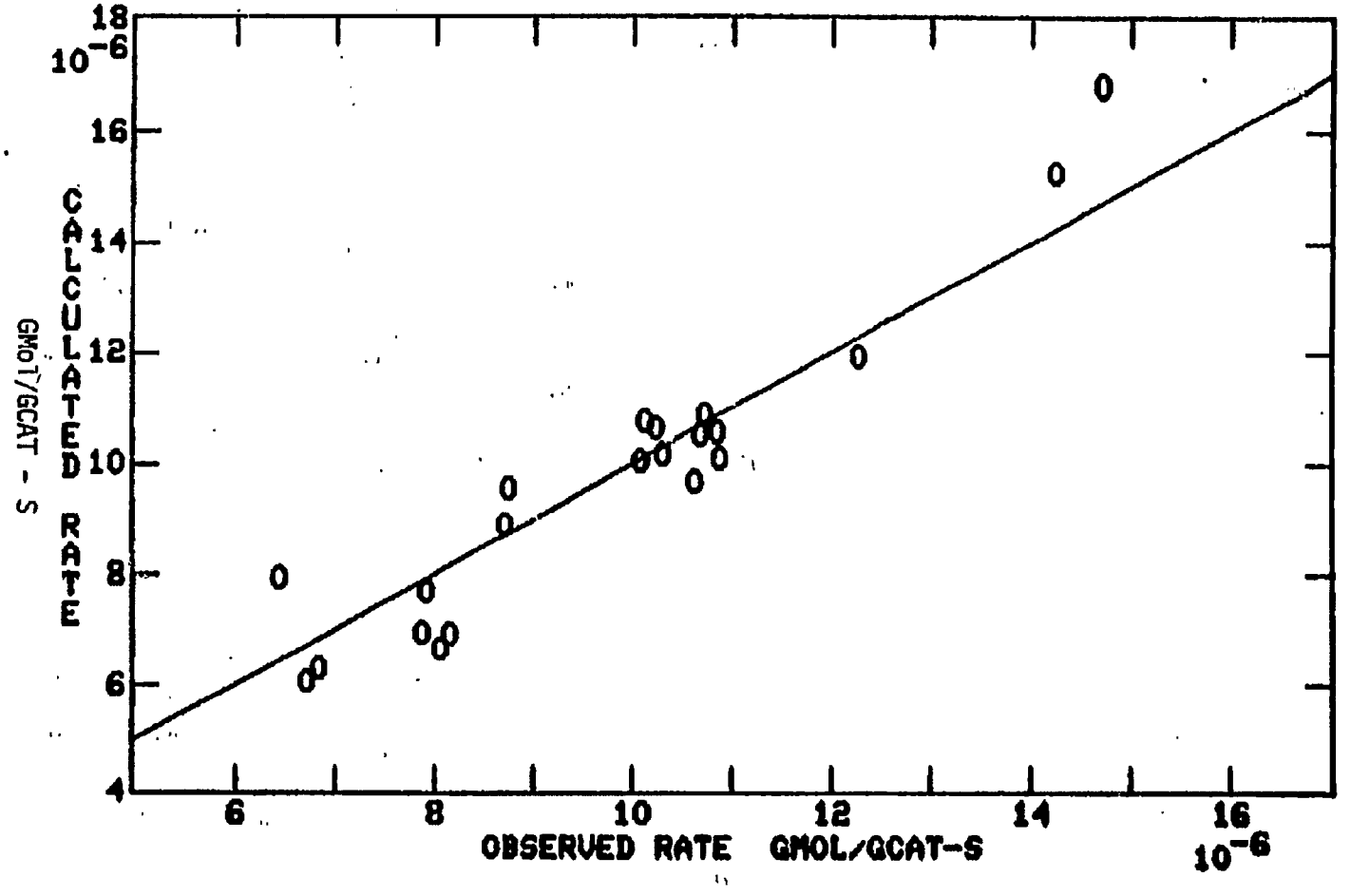


FIGURE 54

Linear Fit for Kinetic Model 4

Temperature = 280°C

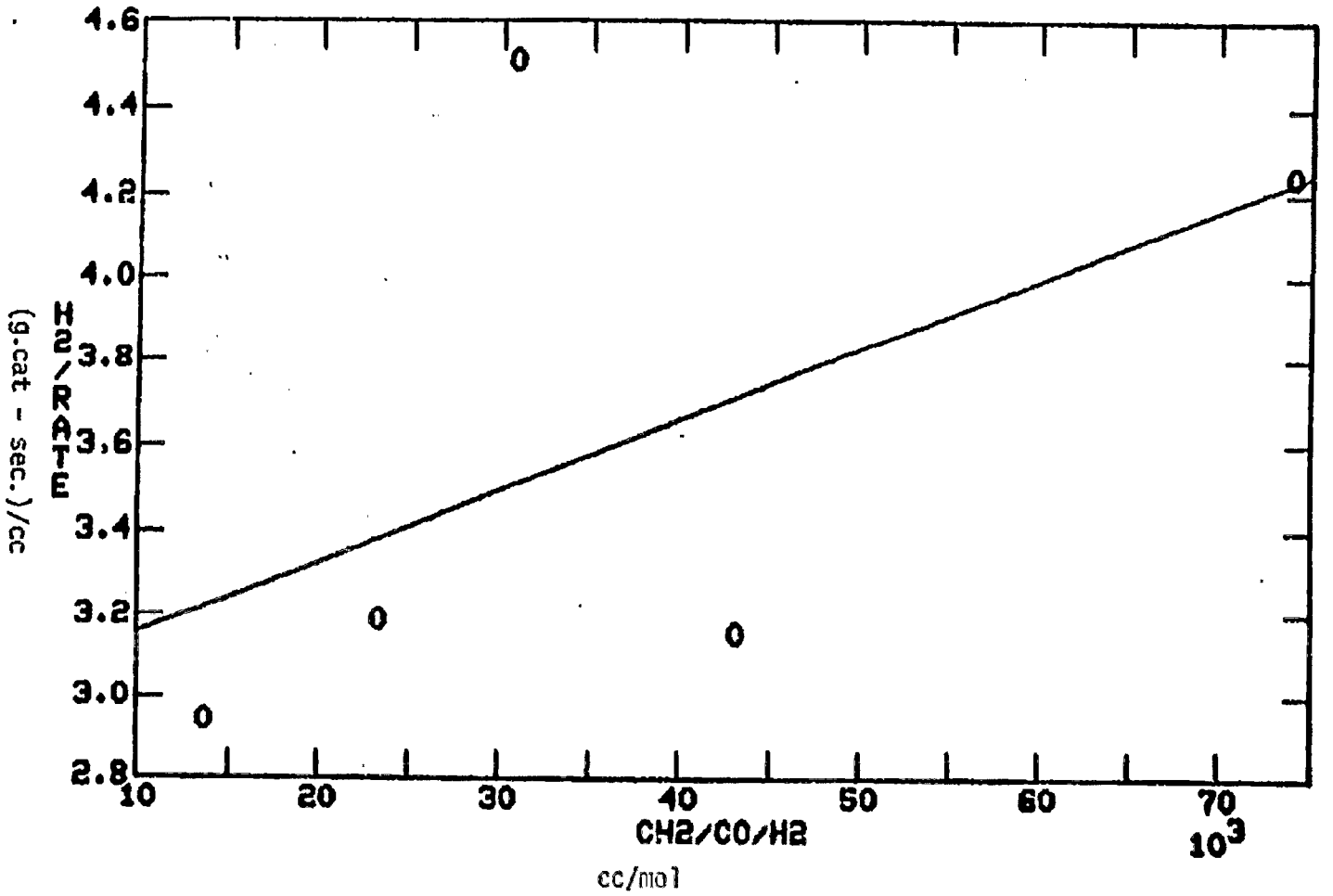


FIGURE 55

Parity Plot for Kinetic Model 4

Temperature = 280°C

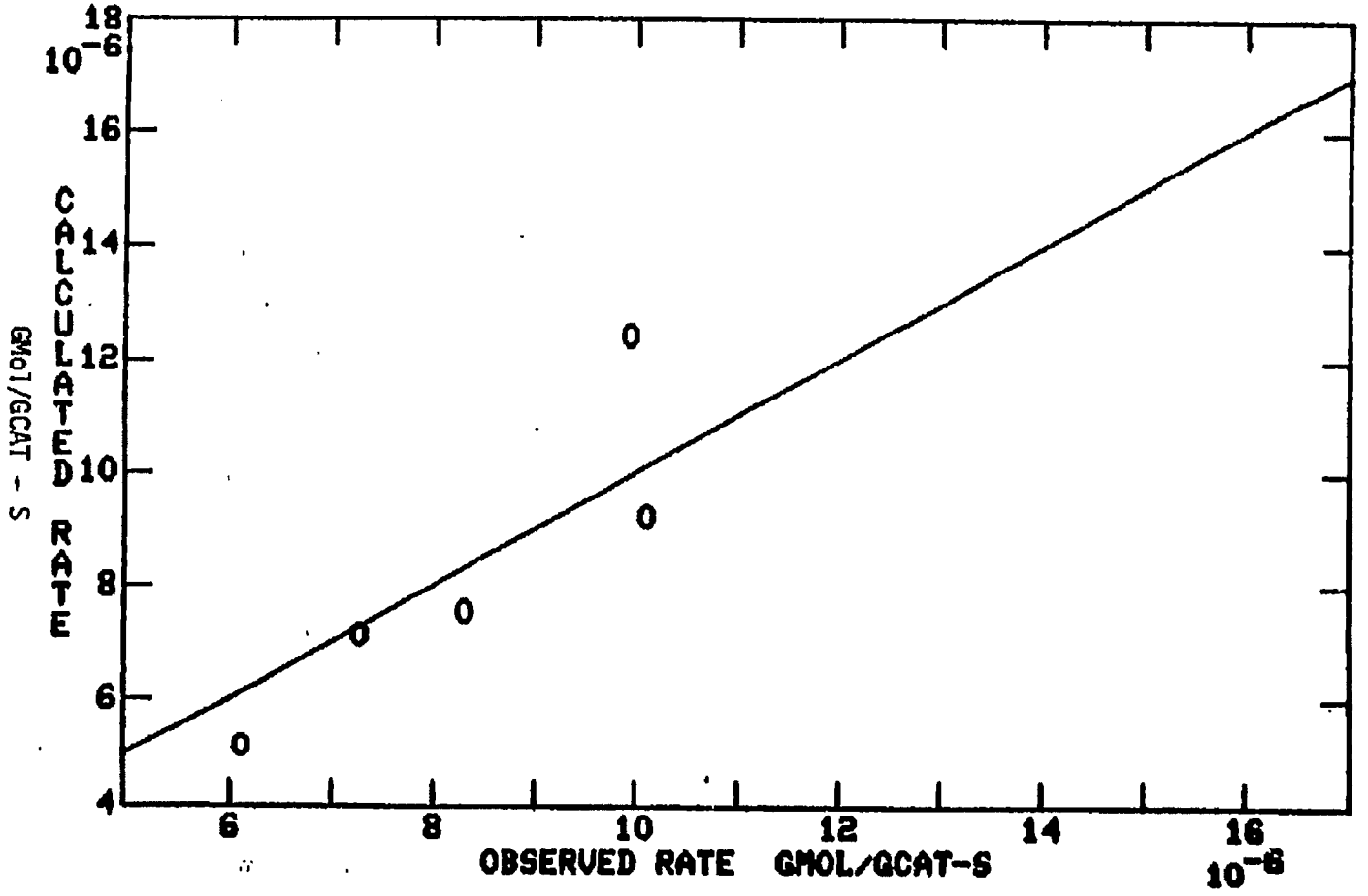


FIGURE 56

Arrhenius Plot = Extended Slurry Test

#8862-1-31

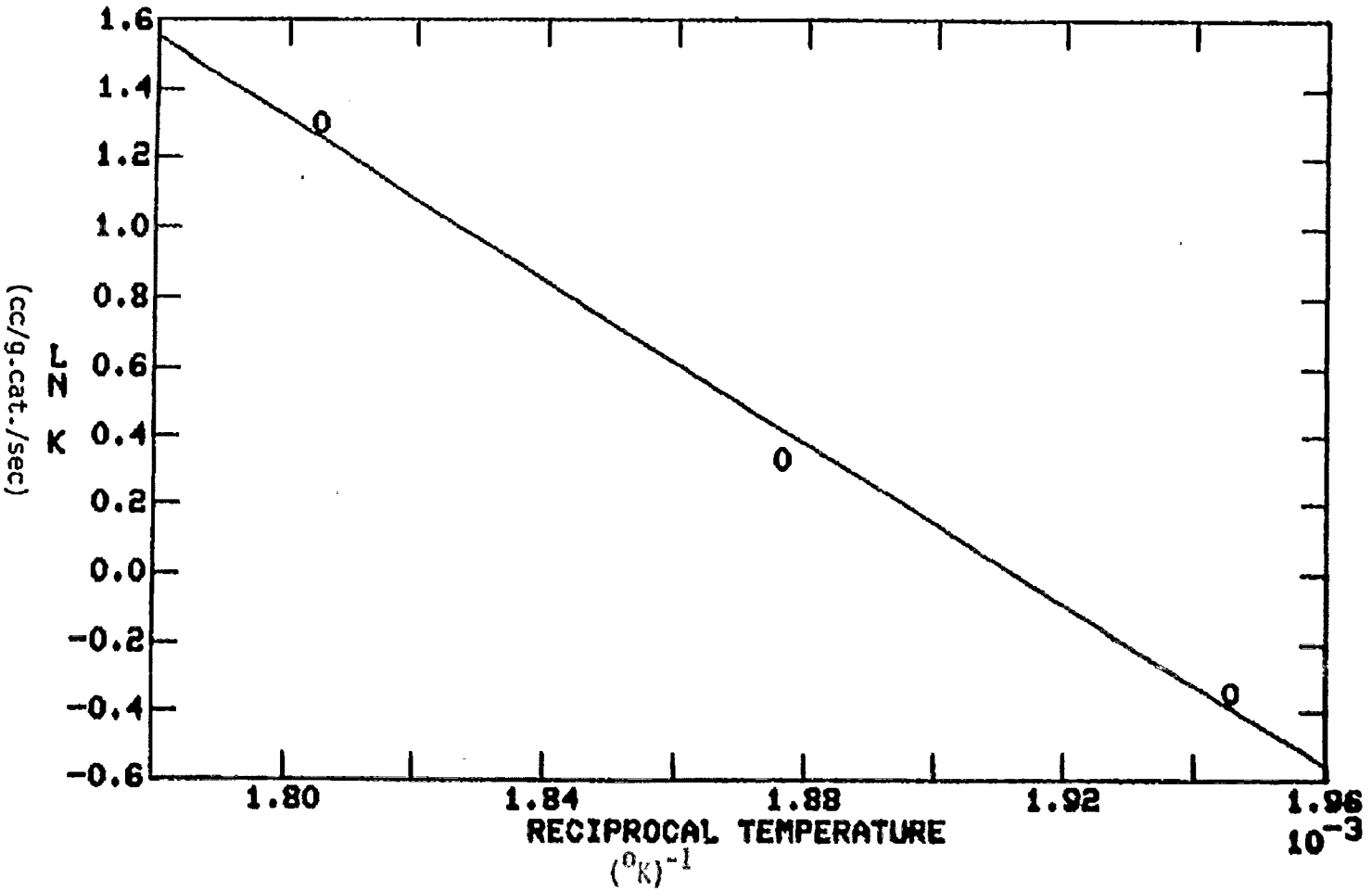
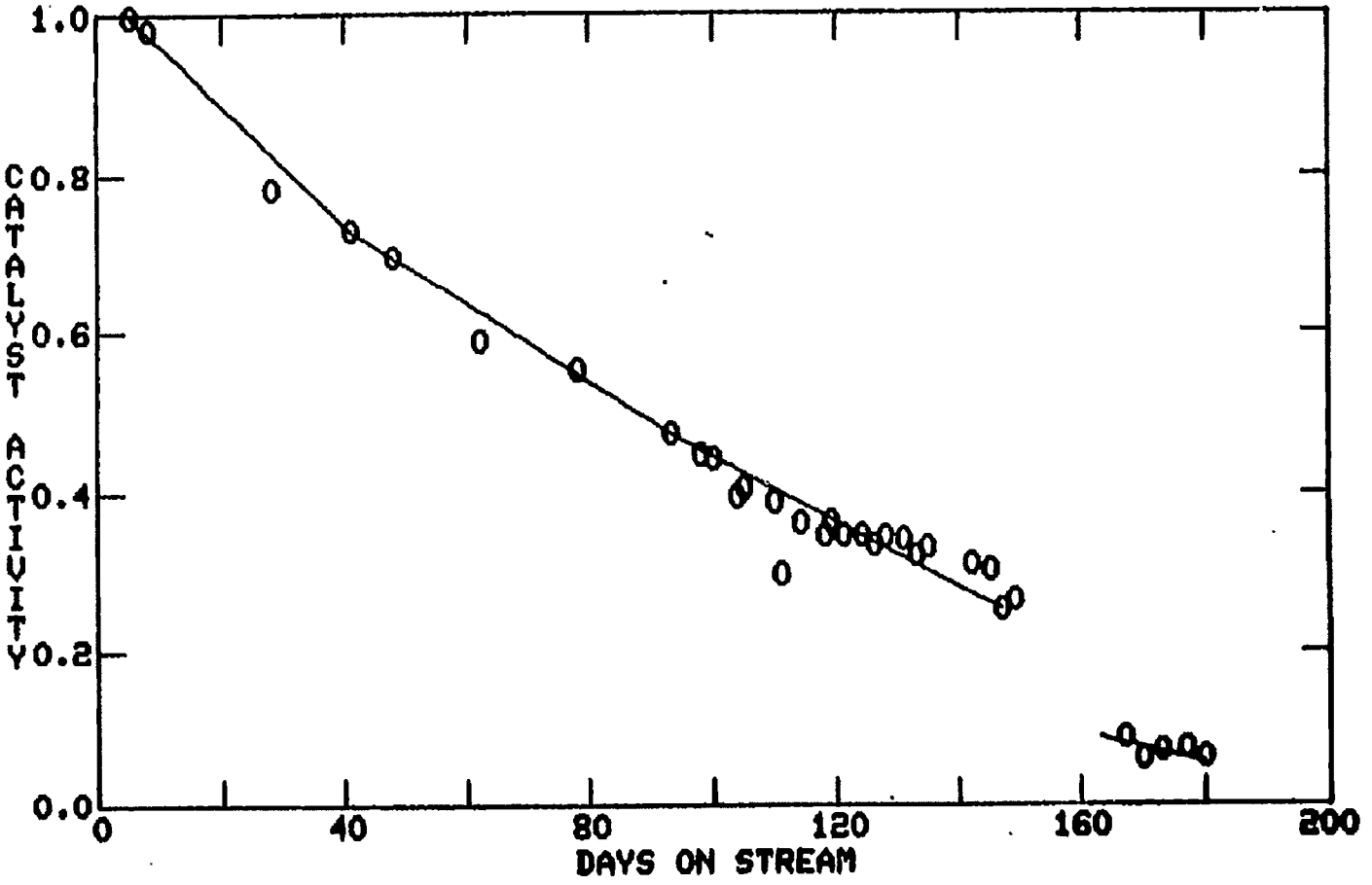


FIGURE 57

Catalyst Deactivation: Extended Slurry Test

#8862-1-31



APPENDIX

Energy Input from Impeller vs. Gas Expansion

a) Calculation of impeller energy input: (Reference 5)

The energy equation is $P = \frac{N_p \rho N^3 D_a^5}{g_c}$

where
- D_a = Impeller diameter = 1.25 in.
- g_c = Gravitational constant
- N = Impeller rotation = 800 rpm
- ρ = Slurry density = 62.4 lb/ft^3 (assumed)
- μ = Slurry viscosity = 1 cp (assumed)

N_p is an empirical number based on Reynold's number from a graph also in Reference 5. For this case, $N_{Re} = \frac{D_a^2 N \rho}{\mu} =$ 13,000. N_p is not sensitive to reasonable variations in N_{Re} in this range so the ρ and μ assumptions are not critical.

The power calculation yields the following:

rpm	Hp
800	$500 \cdot 10^{-6}$
1600	$4000 \cdot 10^{-6}$

b) Calculation of isentropic expansion of gas: (Reference 6)

$$W = \frac{k P_1 V_1}{k-1} \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right]$$

which transforms to Power $= \frac{W}{t} = \frac{kQRT_1}{k-1} \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right]$

Where $k = \frac{C_p}{C_v}$ = 1.4 for diatomic gases

- P_1 & P_2 = Inlet and outlet gas pressure=320 psia & 290 psia*
- Q = Gas flow rate=3000 sccm
- R = Gas constant
- T_1 = Inlet gas temperature=533°K
- t = Time
- w = Work

Substitution of the above values yields:

Δp (psi)	Power (Hp)
30	$1300 \cdot 10^{-6}$
10	$420 \cdot 10^{-6}$

* No differential pressure gauge was available and the individual inlet and outlet gauges were not sufficiently accurate to measure differentials. A sensitivity to this variable is shown above.

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161 (703) 605-6000