CONTINENTAL AIRCRAFT ENGINE CO

Detroit, Michigan

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Curves C-24 & C-25

CONTINENTAL 0-1430-1 ENGINE

Load Analysis of Crankcase, Gearcase, and Support Plate

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LOAD ANALYSIS OF CRANKCASE, GEARCASE, AND SUPPORT PLATE.

References:- Continental O-1430-1 Engine Design Reports No. 55, "Crankpin and Main Bearing Loads", and No. 56, "Load Analysis For Two Propeller Reduction Gear Arrangements"

Object:- The purpose of this analysis is to determine the actual loads on various portions of the reduction gear case and crankcase in order that all loads may be considered and adequately supported. The stresses will be reported separately.

Summary:- The following pages contain an analysis in detail and are self explanatory. The skin of the reduction gear case is subjected to a turning moment equal to two (2) engine torque. The flange and skin between the reduction gear case and crankcase is subjected to a turning moment of one (1) engine torgue. The flange joint between the nose section and reduction gear case is subjected to a turning moment of two (2) engine torque.

The maximum load tending to pull the cylinder from the crankcase is 11,160 lbs. and acts in horizontal direction. The maximum load at the cylinder flange due to piston side thrust is 1805 lbs. and it acts in a vertical plane.

Conclusions:- a The crankcase must be well supported in both the horizontal and vertical planes, and the supporting plate is, in fact, part of the crankcase in load distribution. The necessary strength may be either in the support or the crankcase, however, as the supporting plate has a much longer moment arm against torque than any section of the crankcase, the most economical method of resisting the torque is in the supporting plate.

As the torque reaction is cumulative along the mounting plate toward the rear of the engine, the point on the supporting plate of attachment to the airplane structure will determine the loads in the plate in the following manner:- if the plate is attached at the rear only, the maximum turning force in the plate and crankcase will be two (2) engine torque; if the attachment is made at the center of the engine as well as at the end, the maximum is reduced to $1\frac{1}{2}$ T; while if two points of attachment are provided, one at the front of the engine and one at the rear the extra torque reaction due to the reduction gears is removed entirely from the crankcase and supporting plate, and the maximum turning force in the plate and crankcase would be $\frac{1}{2}$T.

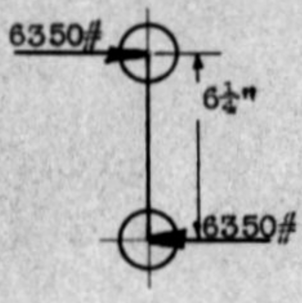
Gear Case Calculations:-

The torque of the engine is multiplied by the reduction gear ratio, hence if T is the engine torque, the torque at the propeller will be 2 T with a 2 to one reduction gear.

Gear Case Calculations:- Cont.

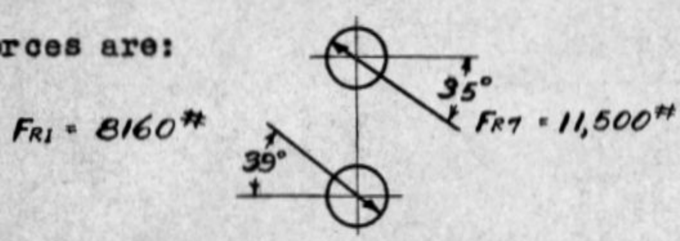
If no reduction gear were used, the front section would be subjected to no torque reaction. However, with the gears the gear case is subjected to an extra stress due to the gears trying to revolve around the mating gear. This tendency to rotate is resisted by the gear shaft bearings. These loads are shown in design report No. 56.

On the forward diaphragm of the gear case, we have the loading conditions as shown below:

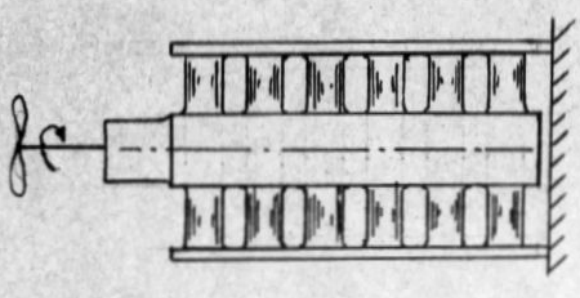


This gives a turning couple of 39,800 in. lbs. which must be transferred thru the flange of the nose section to the gear case section.

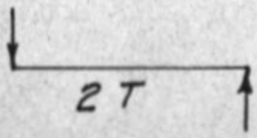
The actual forces are:



The engine itself has a torque reaction of one torque "T". This torque reaction is due to the piston side thrust, and is transferred to the engine supports thru each cylinder barrel.

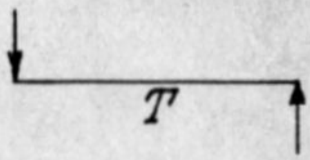


The torque reaction of the propeller "2T", facing the rear of the engine is:-



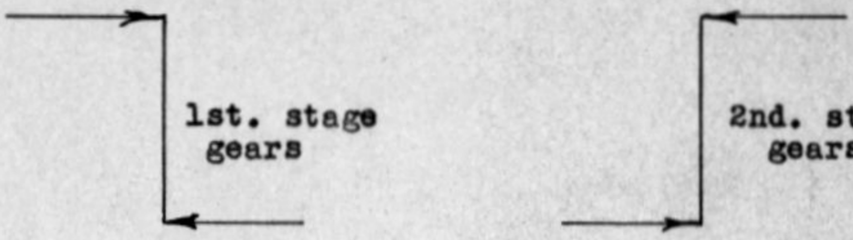
Gear Case Calculations:- Cont.

This reaction must be the total reaction of the engine supports. The crankshaft rotation is in the same direction as the propeller, hence the engine reaction, evidenced in piston side thrust, on the engine supports is:-



This is in the same direction as the necessary propeller torque reaction, hence the torque taken thru the flange of the gear case and crankcase is 2T - T = T. This may be checked by the tangential tooth loads:-

1st. stage:- W = 9.900# at 2.55 in. = 25,200 in lbs.= T
2nd. stage:- W = 13.900# at 3.625 in. = 50,400 in lbs.= 2T



AS these two forces are in the opposite direction, the resultant of the two will be 2T - T = T

The skin of the gear case is subjected to a twisting moment of 2T, one (T) of which is absorbed by the 1st. stage gears and one is transferred to the crankcase.

Crankcase Calculations:-

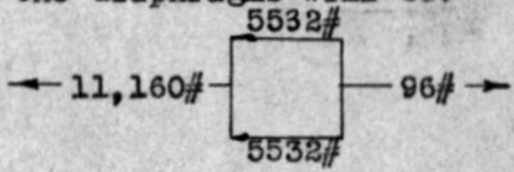
The loads on the crankcase may be classified as follows:- First, the twisting due to the torque reaction; Second, the tension placed in the case by the gas pressure trying to pull the cylinders off the crankcase; Third, the primary and secondary rocking couple existing in the crankcase due to each bank of three cylinders. This is contained in the crankcase itself and tends to break it in half.

(1) We will first consider the torque reaction. Assuming that the torque reaction taken thru the front flange from the gear case is transferred to the supporting plate thru the first cylinder (no. 6), and each succeeding cylinder along the case transfers its side thrust to the supporting plate, the crankcase would not be subjected to any torque reaction, while the supporting plate would be carrying a torque reaction equal to twice engine torque.

<u>Crankcase Calculations</u>:- Cont.

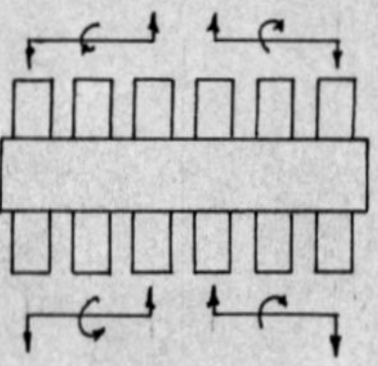
If the supporting plate is sufficiently stiff, this may be accomplished and is one reason why the crankcase design is dependent upon that of its support.

(2) Considering the gas force on the cylinder head as concentrated on the cylinder head of the cylinder the maximum tension in the diaphragms will be:



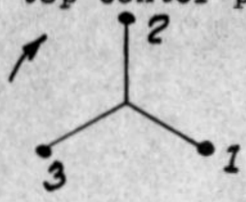
This load is a tension in the horizontal plane, and, combined with the piston side thrust, is the reaction to the bearing loads.

(3) A twelve cylinder engine is inherently balanced as to inertia and centrifugal forces. However, each bank of three cylinders set up a rocking couple as shown on the accompanying sketch:



It is evident that, while these rocking couples balance each other, they set up a force which tends to break the crankcase in half.

Where C = centrifugal force due to masses for one pair of cylinders, and placing #2 pin of the crankshaft at its top center position as shown:



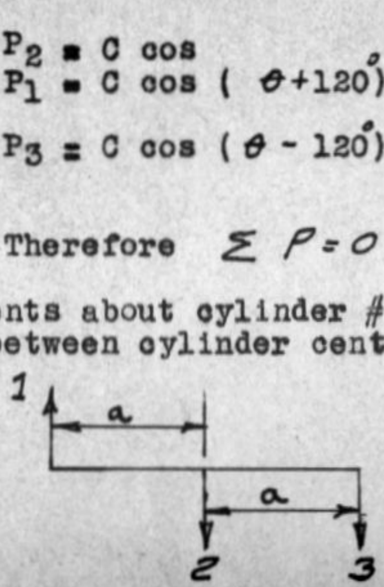
$P_2 = C \cos \qquad = C \cos$

$P_1 = C \cos(\theta + 120^\circ) = C \cos\theta \cos 120^\circ - C \sin\theta \sin 120^\circ$

$P_3 = C \cos(\theta - 120^\circ) = C \cos\theta \cos 120^\circ + C \sin\theta \sin 120^\circ$

Therefore $\Sigma P = 0$

By taking moments about cylinder #2 and letting "a" designate the distance between cylinder centers:



Crankcase Claculations:- Cont.

$$RC = a(P_1 - P_3)$$
$$= -2a\,C\sin\theta\,\sin(120°)$$
$$= -a\sqrt{3}\,C\,\sin\theta$$

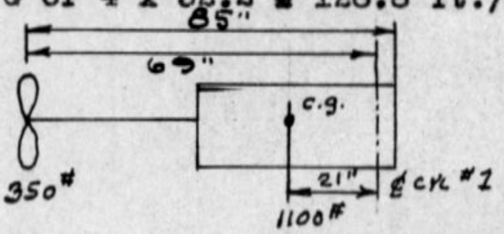
In a similar manner it can be shown that the magnitude of the secondary rocking couple =

$$\text{(Secondary)}\ RC = a\sqrt{3}\,\frac{R}{L}\,C\sin 2\theta$$

for the Continental O-1430-1 engine

Primary RC = 101,000# inches @ 30° behind #1 Pin
Secondary RC = 30,000# inches @ 75° behind #1 Pin

(4) When the airplane is subjected to a rough landing it is possible to put severe bending loads in the crankcase and support. Assuming a rough landing at a speed of approx. 4 G or 4 x 32.2 = 128.8 ft./sec²



$$F = Ma = \frac{350\#}{32.2} \times 128.8 = 1400\#$$

$$= \frac{1100}{32.2} \times 128.8 = 4400\#$$

Bending moment at cylinder head #1 cylinder =

4400 x 21 + 1400 x 69 = 199000# inches

Bending moment at end of support =

4400 x 37 + 1400 x 85 = 281,800# inches.

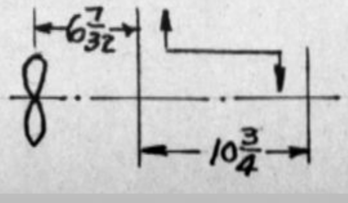
Note:-The crankcase section dimensions and the stresses due to the above forces will be found in tabular form in Design Report #62

(5) Gyroscopic effect in a power dive.

The gyroscopic couple = $I\,\omega_r\,\omega_1$
I (Polar moment of inertia of propeller) = 1296 lbs ft²
(Estimated by Hamilton Standard Propeller Co.)

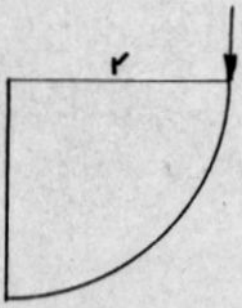
ω_r for 1500 RPM = $\frac{2\pi N}{60}$ = 157 Rad. per sec.

For 30% overspeed ω_r = 194 Rad. per sec.



Crankcase Calculations:- Cont.

ω_1 (For pull out from dive Max. acc.) = 8g



$$\frac{v^2}{r} = 8g$$

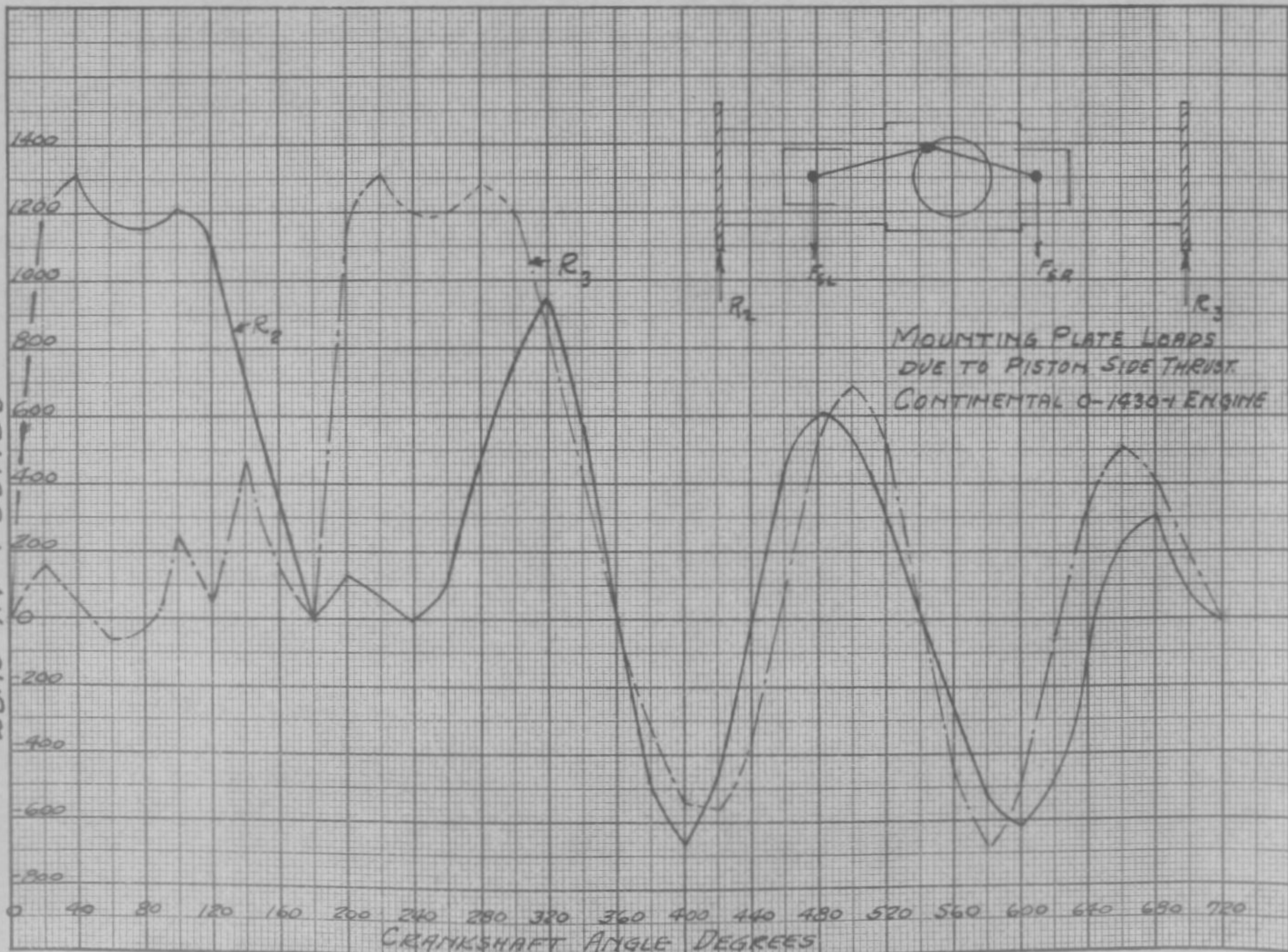
$$\frac{(880)^2}{8 \times 32.2} = r = 3000 \text{ ft}$$

$$\omega_1 = \frac{v}{r} = \frac{880}{3000} = 0.293 \text{ Rad. per sec.}$$

Gyroscopic Couple = $\frac{1296}{32.2} \times 157 \times .293 = 1850$ lbs ft.

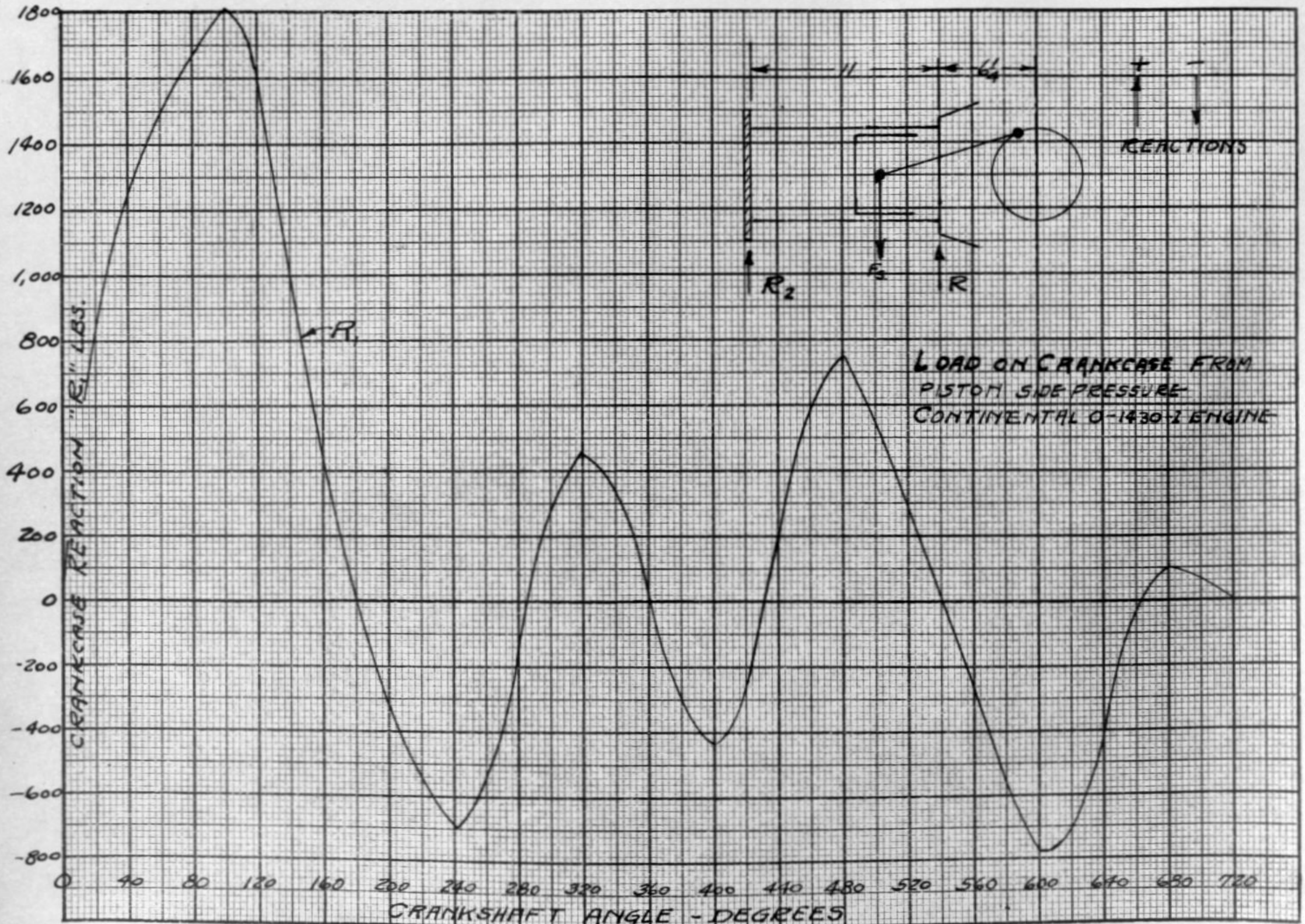
$\frac{1850 \times 12}{10.75} = 2065$ lbs.

For 30% overspeed and an acceleration of 10g
Gyroscopic couple = 2580 lbs.



Mounting Plate Loads
due to Piston Side Thrust
Continental O-1430-1 Engine
R_2
R_3
F_{SL}
F_{SR}
Load in Pounds
Crankshaft Angle Degrees
1400
1200
1000
800
600
400
200
0
-200
-400
-600
-800
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
640
680
720

C-24


LOAD ON CRANKCASE FROM
PISTON SIDE PRESSURE
CONTINENTAL O-1430-1 ENGINE
CRANKCASE REACTION "R1" LBS.
CRANKSHAFT ANGLE - DEGREES
R1
REACTIONS
+
−
11
6¼
R2
F1
R
1800
1600
1400
1200
1,000
800
600
400
200
0
-200
-400
-600
-800
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
640
680
720