ENGINE MOUNTING DESIGN CONSIDERATIONS

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BARRY™ CONTROLS
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BULLETIN RR-L

Engine Mounting Design Considerations

There are many good reasons to resiliently mount an engine and/or transmission. One increasingly important reason is to reduce structureborne noise and vibration generated by the engine and transmitted to the vehicles operator compartment. Resilient mounting will also provide longer life for frame and engine block mounting brackets, suspended components and transmission by attenuating transient shock inputs and operating torque loads. The following discussion summarizes engine disturbances, looks at several ideal and practical mounting approaches and points out important limiting mounting considerations. Finally,selection criteria and required data for proper engine mounting are outlined.

Disturbances

1. Torsional dynamic pulses due to variations in cylinder gas pressure.

   2 cycle engine - f_d(disturbing frequency) = RPM x no. of cyl.

   4 cycle engine - f_d(disturbing frequency) = $\frac{\text{RPM x no. of cyl.}}{2}$

   For practical mounting solutions isolate the fundamental first order or RPM.

   2 cycle - isolate RPM

   4 cycle - isolate RPM/2

2. Imbalance forces due to reciprocating or rotating masses within the engine.

   1 cylinder engine - isolate the primary vertical and horizontal inertia forces.

   2 cylinder engine - isolate the secondary rotating inertia forces.

   For other engine types, the modes of primary and secondary inertia forces are given in Figures I and II.

   Translational and rotational modes of an engine are shown in Figure III. X, y, and z are the principal axes of the engine and exhibit the least moment of inertial forces. Mounts should be located to allow free vibration about these principal inertia axes, particularly the roll axis, for good isolation.

Decoupled Mounting Systems

A decoupled mounting system is achieved when the elastic center of the isolators coencides with the combined center of gravity of the engine and transmission. This type of system is desirable because a coupled system is less stable for the same degree of isolation than a decoupled system. The softest mode of vibration (stiffness) should be in the rotational (torsional) axis.

Mounting Considerations - (Practical)

1. Mount locations (see figure IV)

   The engine is not a rigid mass but actually a free-free beam in space. Mounts should be positioned at the nodal points.

2. Stability

   Mounts should provide stability for the following conditions:

   Fore-aft: up to 7g's
   Lateral: 1g
   Vertical: 3-4g's
   Torsional: Engine manufactures' rated torque x 2

3. Frame and bracket stiffness

   The stiffness of attached mounting brackets and support frame are important to the performance of the mounting system and should be designed to be as stiff as possible. The effective stiffness of the mounting system, when the support structure is less than 10 times stiffer than the isolators, can be determined from the following formula:

   $$K\ \text{effective} = \frac{K\ \text{support} \times K\ \text{mounts}}{K\ \text{support} + K\ \text{mounts}}$$

   This effective stiffness should then be used to determine the performance of the spring mass system.

Practical Solutions

1. Automotive - 1957 Buick "Nodal Point" Engine Mounting System (see Figure V)

   Note that the engine mounts are located at the bending nodal points of the engine.

2. Industrial Vehicles - Three Point Mounting (see Figure VI)

   This system was designed to accommodate easy engine removal and maintenance. Due to a badly coupled condition, the roll frequency is increased and poor isolation results at idle and low operating speeds.

3. Automotive - Generally use focused three point mounting system (see figure VII)

   Focused mounts provide decoupled stable response but the mount locations do not limit engine bending.

Focused Engine Mounts

(see figure VIII)

In order to effectively decouple a mounting system, focused mounts can be employed. The mounts should be focused above the principal roll axis (the minimum axis of inertia). Barry 500 and 22000 series isolators exhibit a one to one stiffness ratio and cannot be effectively focused. Several special Barry ring and bushing designs have been developed for this purpose. They are:

P/N 22164 - Kc/Ks = 6
P/N 21959 - Kc/Ks = 2.6

Selection of Engine Mounts

There are three normal loading conditions which must be considered when selecting engine mounts. They are:

Static loads - weight of engine and accessories
Dynamic loads - transiet shock levels
Torque loads - manufacturers ratings

For static load limits in terms of stress and strain on the Barry 22000 series, refer to figure IX.

Torque loads can be determined from the following formula if manufactures ratings are not available:

$$T \text{ (in-lbs)} = \frac{63{,}000 \times HP}{RPM}$$

HP = engine horse power

RPM = output of transmission

Data Required for Engine Mounting Analysis

Provide the data required in figure X when requesting an engine mounting recommendation from Barry engineering. Moment of inertia data may not be available but can be estimated if the overall outline of the engine and transmission can be provided.

FIGURE # I

TYPE ON ENGINE	CRANK ARRANGEMENT	INERTIA FORCES PRIMARY RPM	INERTIA FORCES SECONDARY 2xRPM	COUPLE OF MOMENT PRIMARY RPM	COUPLE OF MOMENT SECONDARY 2xRPM
ONE CYLINDER	1	VERTICAL HORIZONTAL	VERTICAL	NONE	NONE
TWO CYLINDER VERTICAL	1-2		VERTICAL	PITCH YAW	
TWO CYLINDER OPPOSED	1 2			YAW	YAW
THREE CYLINDER VERTICAL	1-2-3			PITCH YAW	YAW
FOUR CYLINDER VERTICAL	1-2-3-4		VERTICAL		
FOUR CYLINDER VERTICAL	1-2-3-4			PITCH YAW	
SIX CYLINDER VERTICAL	1-2-3-4-5-6				
SIX CYLINDER VERTICAL	1-2-3-4-5-6			PITCH YAW	

2 CYCLE-CPM = (NO. CYLINDERS)(RPM) } TORQUE
4 CYCLL-CPM = (NO. CYLINDERS / 2) (RPM) } 1ST. ORDER

FIGURE # II

TYPE OF ENGINE	CRANK ARRANGEMENT	INERTIA FORCES PRIMARY RPM	INERTIA FORCES SECONDARY 2xRPM	COUPLE OF MOMENT PRIMARY RPM	COUPLE OF MOMENT SECONDARY 2xRPM
2 CYLINDER HORIZONTAL	2 1	VERTICAL			
4 CYLINDER HORIZONTAL	1,2 3,4			YAW	
4 CYLINDER HORIZONTAL	1,4 2,3				YAW
2 CYLINDER 90° V	1-2		HORIZONTAL		
2 CYLINDER 60° V	1-2	VERTICAL			
8 CYLINDER 90° V	1-2-7-8 3-4-5-6		HORIZONTAL		
8 CYLINDER 90° V	1-2 3,4 5,6 7-8				
8 CYLINDER 60° V	1-2-7-8 3-4-5-6				

FIGURE III

TRANSLATIONAL AND ROTATIONAL MODES

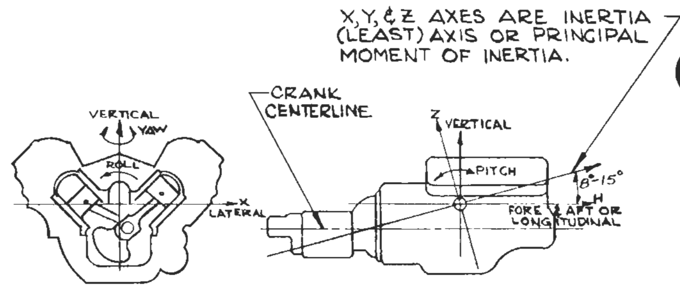

FIGURE IV

ENGINE NODAL POINTS

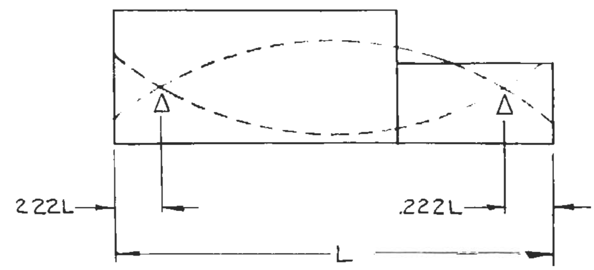

FIGURE V

ENGINE MOUNTS FOR A 1957 BUICK

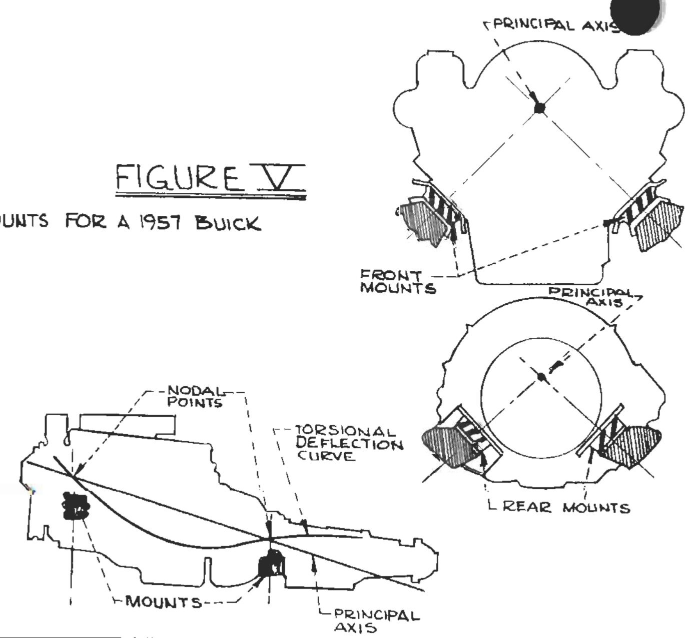

FIGURE VI

INDUSTRIAL THREE POINT MOUNTING SYSTEM

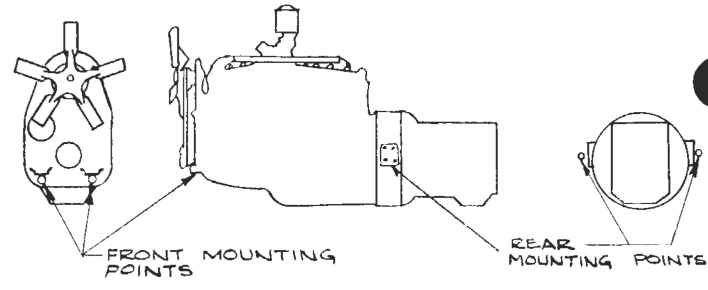

FIGURE VII

FOCUSED THREE POINT MOUNTING SYSTEM

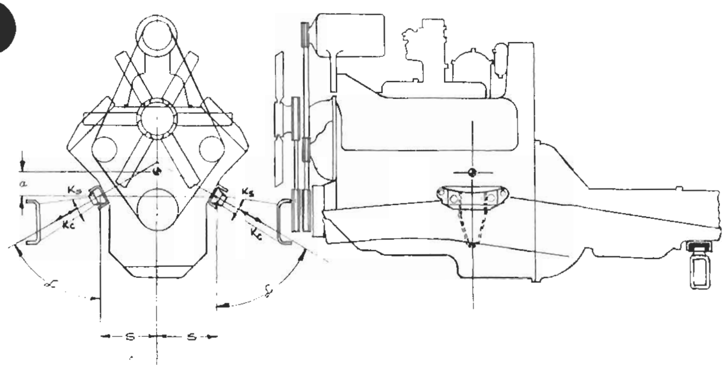

FIGURE # IX

ISØLATOR	AXIAL *LOAD #	*LOAD #
	10% STRAIN LIMIT	125 PSI STRESS LIMIT
22001-1	50	——
22001-2	110	——
22001-3	(160)	125
22001-4	(250)	125
22001-5	(360)	125
22002-1	90	——
22002-2	160	——
22002-3	(225)	200
22002-4	(325)	200
22002-5	(500)	200
22003-1	160	——
22003-2	250	——
22003-3	375	——
22003-4	(525)	400
22003-5	(730)	400
22004-1	350	——
22004-2	600	——
22004-3	(850)	700
22004-4	(1200)	700
22004-5	(1800)	700
22005-1	700	——
22005-2	1200	——
22005-3	(1800)	1700
22005-4	(2600)	1700
22005-5	(3400)	1700

*FOR BLACK RUBBER COMPOUNDS

FIGURE VIII

ROLL AXIS HEIGHT/INCLINATION RELATIONSHIP

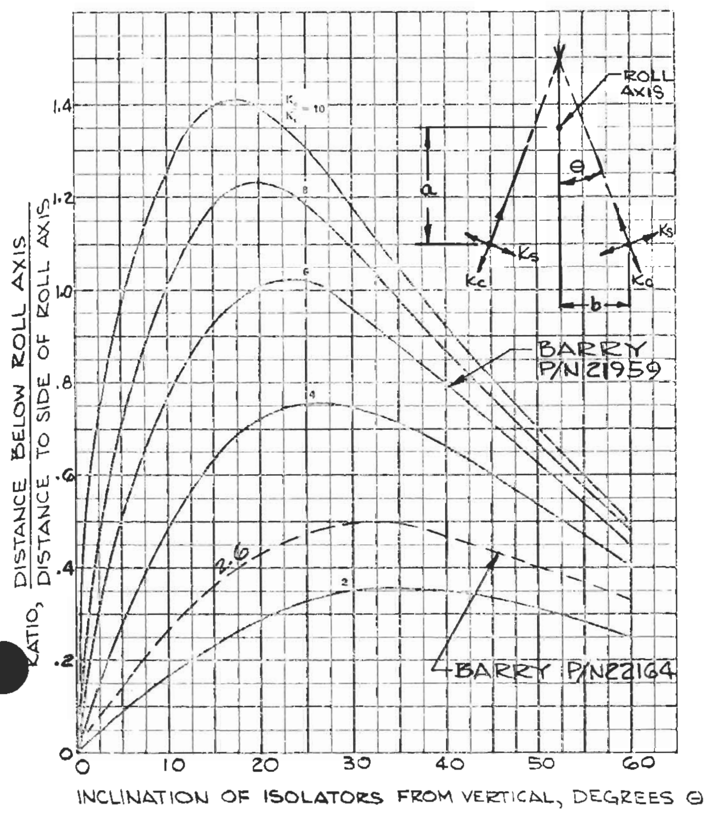

FIGURE X

DATA REQUIRED FOR ENGINE MOUNT DESIGN

A. ENGINE DATA:

1. ENGINE MODEL AND MANUFACTURER.
2. TOTAL WEIGHT OF ENGINE AND ALL ACCESSORIES.
3. MOMENTS OF INERTIA FOR COMPLETE ENGINE FOR ROLL, PITCH AND YAW MODES
4. ENGINE OPERATING SPEEDS.
5. NUMBER OF CYLINDERS.
6. FIRING SEQUENCE.
7. CRANKSHAFT ARRANGEMENT.
8. DEVELOPED ENGINE TORQUE.
9. GEAR REDUCTION RATIO.
10. ENGINE LAYOUT DRAWING SHOWING:
    a. LOCATION OF MOUNTING ATTACHING POINTS.
    b. DETAILS OF MOUNTING ATTACHING POINTS.
    c. LOCATION OF C.G. FOR ALL SUSPENDED COMPONENTS.
11. TYPE OF SERVICE

B. STRUCTURAL DATA

1. DESCRIPTION OR DRAWING OF STRUCTURE TO SUPPORT ENGINE.
2. SPACE LIMITATIONS — TO DETERMINE MOUNTING SIZE.
3. MINIMUM CLEARANCE — TO DETERMINE MAXIMUM ENGINE MOTION.
4. MOUNTING POINT TEMPERATURE — IF ABOVE 170° F.