In [1]:
```
import pandas as pd
import tensorflow as tf
import seaborn as sns
import numpy as np
import matplotlib.pyplot as plt
from tensorflow import keras
from tensorflow.keras import layers
```

In [2]:
```
url = 'http://archive.ics.uci.edu/ml/machine-learning-databases/auto-mpg/auto-mpg.data'

column_names = ['MPG', 'Cylinders', 'Displacement', 'Horsepower', 'Weight',
                'Acceleration', 'Model Year', 'Origin']

raw_dataset = pd.read_csv(url, names=column_names,
                          na_values='?', comment='\t',
                          sep=' ', skipinitialspace=True)
```

In [3]:
```
dataset = raw_dataset.copy()
dataset.tail()
```

Out[3]:

	MPG	Cylinders	Displacement	Horsepower	Weight	Acceleration	Model Year	Origin
393	27.0	4	140.0	86.0	2790.0	15.6	82	1
394	44.0	4	97.0	52.0	2130.0	24.6	82	2
395	32.0	4	135.0	84.0	2295.0	11.6	82	1
396	28.0	4	120.0	79.0	2625.0	18.6	82	1
397	31.0	4	119.0	82.0	2720.0	19.4	82	1

In [4]:
```
dataset.isna().sum()
```

Out[4]:
```
MPG             0
Cylinders       0
Displacement    0
Horsepower      6
Weight          0
Acceleration    0
Model Year      0
Origin          0
dtype: int64
```

In [5]:
```
dataset = dataset.dropna()
```

In [6]:
```
dataset.isna().sum()
```

Out[6]:
```
MPG             0
Cylinders       0
Displacement    0
Horsepower      0
Weight          0
Acceleration    0
Model Year      0
Origin          0
dtype: int64
```

In [7]:
```
dataset.head(15)
```

Out[7]:

	MPG	Cylinders	Displacement	Horsepower	Weight	Acceleration	Model Year	Origin
0	18.0	8	307.0	130.0	3504.0	12.0	70	1
1	15.0	8	350.0	165.0	3693.0	11.5	70	1
2	18.0	8	318.0	150.0	3436.0	11.0	70	1
3	16.0	8	304.0	150.0	3433.0	12.0	70	1
4	17.0	8	302.0	140.0	3449.0	10.5	70	1
5	15.0	8	429.0	198.0	4341.0	10.0	70	1
6	14.0	8	454.0	220.0	4354.0	9.0	70	1
7	14.0	8	440.0	215.0	4312.0	8.5	70	1
8	14.0	8	455.0	225.0	4425.0	10.0	70	1
9	15.0	8	390.0	190.0	3850.0	8.5	70	1
10	15.0	8	383.0	170.0	3563.0	10.0	70	1
11	14.0	8	340.0	160.0	3609.0	8.0	70	1
12	15.0	8	400.0	150.0	3761.0	9.5	70	1
13	14.0	8	455.0	225.0	3086.0	10.0	70	1
14	24.0	4	113.0	95.0	2372.0	15.0	70	3

In [8]:
```
dataset['Origin'].unique()
```

Out[8]:
```
array([1, 3, 2], dtype=int64)
```

In [9]:
```
dataset['Origin'] = dataset['Origin'].map({1: 'USA', 2: 'Europe', 3: 'Japan'})
```

In [10]:
```
dataset.head()
```

Out[10]:

	MPG	Cylinders	Displacement	Horsepower	Weight	Acceleration	Model Year	Origin
0	18.0	8	307.0	130.0	3504.0	12.0	70	USA
1	15.0	8	350.0	165.0	3693.0	11.5	70	USA
2	18.0	8	318.0	150.0	3436.0	11.0	70	USA
3	16.0	8	304.0	150.0	3433.0	12.0	70	USA
4	17.0	8	302.0	140.0	3449.0	10.5	70	USA

In [11]:
```
dataset = pd.get_dummies(dataset, columns=['Origin'])
```

In [12]:
```
dataset.head(10)
```

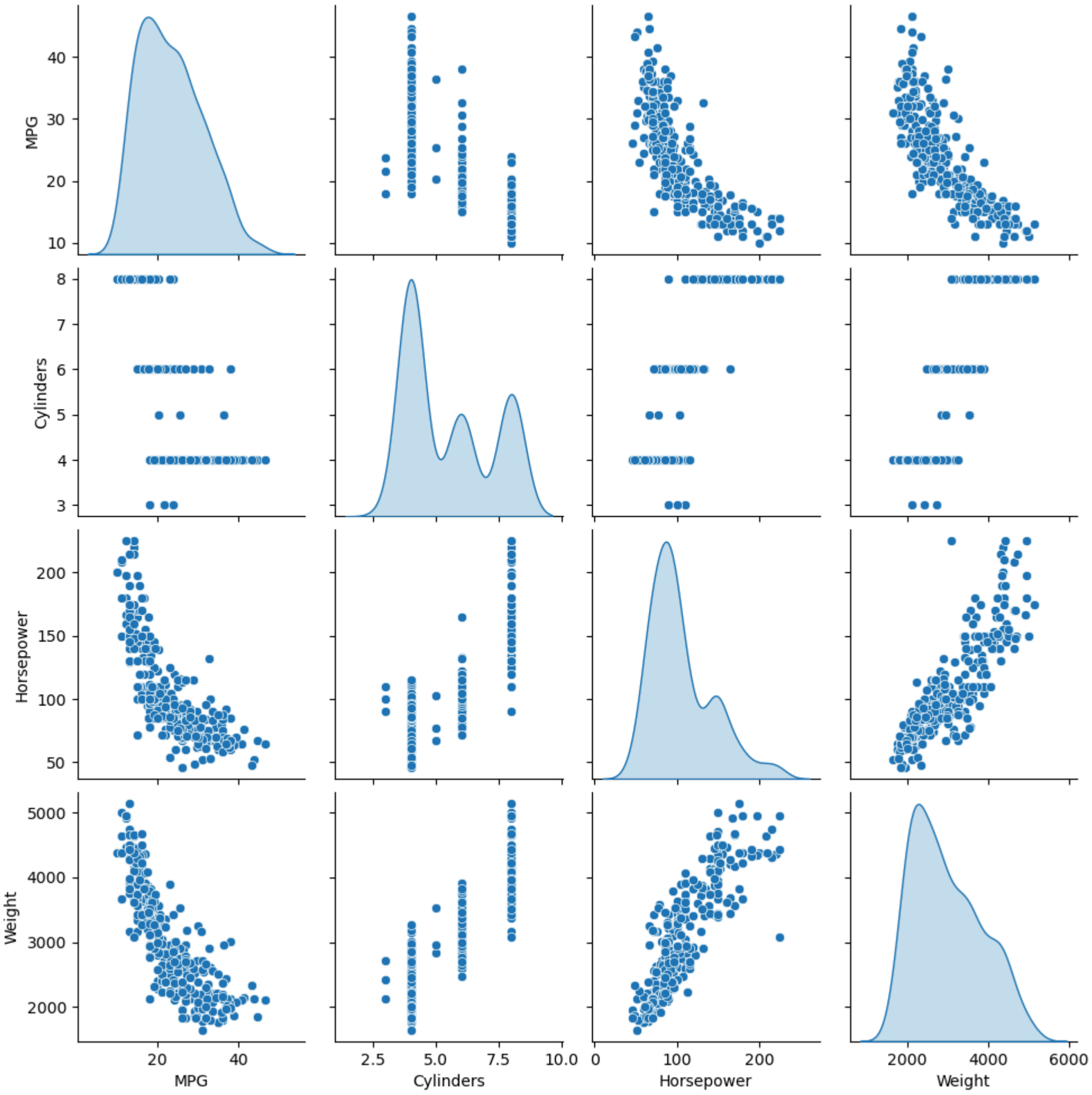
Out[12]:

	MPG	Cylinders	Displacement	Horsepower	Weight	Acceleration	Model Year	Origin_Europe	Origin_Japan	Origin_USA
0	18.0	8	307.0	130.0	3504.0	12.0	70	0	0	1
1	15.0	8	350.0	165.0	3693.0	11.5	70	0	0	1
2	18.0	8	318.0	150.0	3436.0	11.0	70	0	0	1
3	16.0	8	304.0	150.0	3433.0	12.0	70	0	0	1
4	17.0	8	302.0	140.0	3449.0	10.5	70	0	0	1
5	15.0	8	429.0	198.0	4341.0	10.0	70	0	0	1
6	14.0	8	454.0	220.0	4354.0	9.0	70	0	0	1
7	14.0	8	440.0	215.0	4312.0	8.5	70	0	0	1
8	14.0	8	455.0	225.0	4425.0	10.0	70	0	0	1
9	15.0	8	390.0	190.0	3850.0	8.5	70	0	0	1

In [13]:
```
train_dataset = dataset.sample(frac=0.8, random_state=0)
test_dataset = dataset.drop(train_dataset.index)
```

In [14]:
```
sns.pairplot(train_dataset[['MPG', 'Cylinders', 'Horsepower', 'Weight']], diag_kind='kde')
```

Out[14]:
```
<seaborn.axisgrid.PairGrid at 0x212cbed8750>
```



In [15]:
```
train_dataset.describe().transpose()
```

Out[15]:

	count	mean	std	min	25%	50%	75%	max
MPG	314.0	23.310510	7.728652	10.0	17.00	22.0	28.95	46.6
Cylinders	314.0	5.477707	1.699788	3.0	4.00	4.0	8.00	8.0
Displacement	314.0	195.318471	104.331589	68.0	105.50	151.0	265.75	455.0
Horsepower	314.0	104.869427	38.096214	46.0	76.25	94.5	128.00	225.0
Weight	314.0	2990.251592	843.898596	1649.0	2256.50	2822.5	3608.00	5140.0
Acceleration	314.0	15.559236	2.789230	8.0	13.80	15.5	17.20	24.8
Model Year	314.0	75.898089	3.675642	70.0	73.00	76.0	79.00	82.0
Origin_Europe	314.0	0.178344	0.383413	0.0	0.00	0.0	0.00	1.0
Origin_Japan	314.0	0.197452	0.398712	0.0	0.00	0.0	0.00	1.0
Origin_USA	314.0	0.624204	0.485101	0.0	0.00	1.0	1.00	1.0

In [16]:
```
train_features = train_dataset.copy()
test_features = test_dataset.copy()

train_labels = train_features.pop('MPG')
test_labels = test_features.pop('MPG')
```

In [17]:
```
train_dataset.describe().transpose()[['mean', 'std']]
```

Out[17]:

	mean	std
MPG	23.310510	7.728652
Cylinders	5.477707	1.699788
Displacement	195.318471	104.331589
Horsepower	104.869427	38.096214
Weight	2990.251592	843.898596
Acceleration	15.559236	2.789230
Model Year	75.898089	3.675642
Origin_Europe	0.178344	0.383413
Origin_Japan	0.197452	0.398712
Origin_USA	0.624204	0.485101

In [18]:
```
normalizer = tf.keras.layers.Normalization(axis=-1)
normalizer.adapt(np.array(train_features))
print(normalizer.mean.numpy())
```

```
[[5.47770691e+00 1.95318497e+02 1.04869446e+02 2.99025171e+03
  1.55592356e+01 7.58980942e+01 1.78343967e-01 1.97452217e-01
  6.24203861e-01]]
```

In [19]:
```
first = np.array(train_features[:1])


with np.printoptions(precision=2, suppress=True):
  print('First example:', first)
  print()
  print('Normalized:', normalizer(first).numpy())
```

```
First example: [[   4.    90.    75.  2125.    14.5   74.     0.     0.     1. ]]

Normalized: [[-0.87 -1.01 -0.79 -1.03 -0.38 -0.52 -0.47 -0.5   0.78]]
```

SLR

In [20]:
```
horsepower = np.array(train_features['Horsepower'])

horsepower_normalizer = layers.Normalization(input_shape=[1,], axis=None)
horsepower_normalizer.adapt(horsepower)
```

In [21]:
```
horsepower_model = tf.keras.Sequential([
    horsepower_normalizer,
    layers.Dense(units=1)
])

horsepower_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization_1 (Normaliza  (None, 1)                 3
 tion)

 dense (Dense)               (None, 1)                 2

=================================================================
Total params: 5 (24.00 Byte)
Trainable params: 2 (8.00 Byte)
Non-trainable params: 3 (16.00 Byte)
_________________________________________________________________
```

In [22]:
```
horsepower_model.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate=0.1),
    loss='mean_absolute_error')
```

In [23]:
```
%%time
history = horsepower_model.fit(
    train_features['Horsepower'],
    train_labels,
    epochs=100,
    verbose=0,
    validation_split = 0.2)
```

```
CPU times: total: 6 s
Wall time: 4.89 s
```

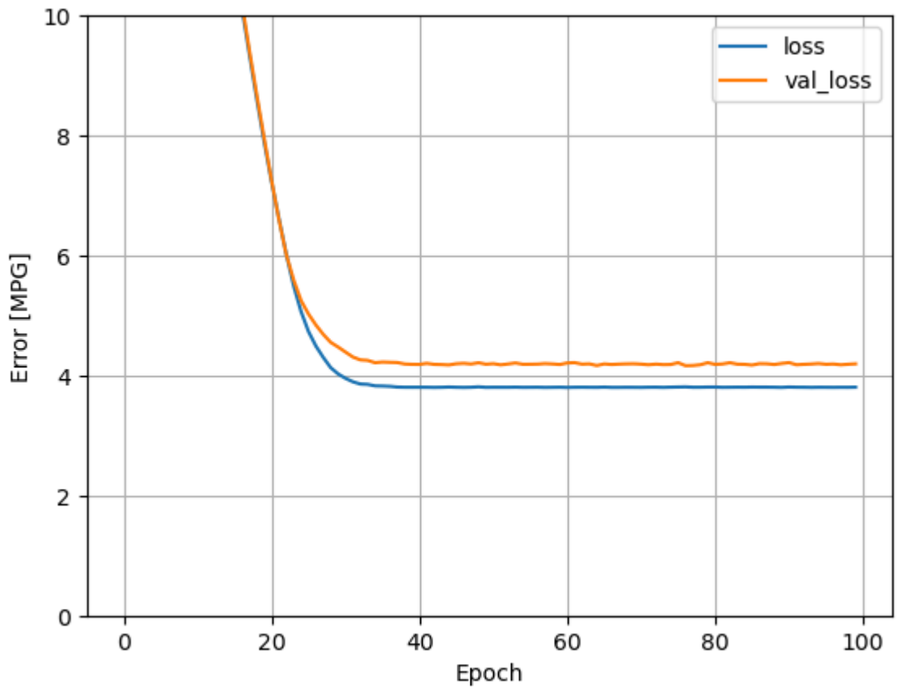
In [24]:
```
hist = pd.DataFrame(history.history)
hist['epoch'] = history.epoch
hist.tail()
```

Out[24]:

	loss	val_loss	epoch
95	3.803825	4.187245	95
96	3.802713	4.191550	96
97	3.803993	4.179204	97
98	3.803464	4.187901	98
99	3.805697	4.194726	99

In [25]:
```
def plot_loss(history):
  plt.plot(history.history['loss'], label='loss')
  plt.plot(history.history['val_loss'], label='val_loss')
  plt.ylim([0, 10])
  plt.xlabel('Epoch')
  plt.ylabel('Error [MPG]')
  plt.legend()
  plt.grid(True)
```

In [26]:
```
plot_loss(history)
```



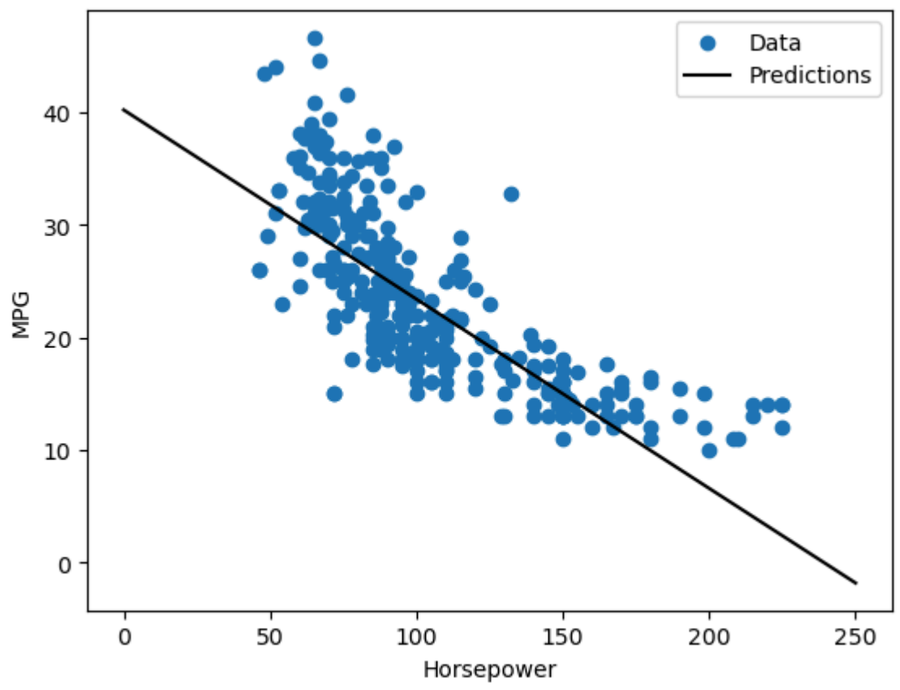
In [27]:
```
test_results = {}

test_results['horsepower_model'] = horsepower_model.evaluate(
    test_features['Horsepower'],
    test_labels, verbose=0)
```

In [28]:
```
x = tf.linspace(0.0, 250, 251)
y = horsepower_model.predict(x)
```

```
8/8 [==============================] - 0s 2ms/step
```

In [29]:
```
def plot_horsepower(x, y):
  plt.scatter(train_features['Horsepower'], train_labels, label='Data')
  plt.plot(x, y, color='k', label='Predictions')
  plt.xlabel('Horsepower')
  plt.ylabel('MPG')
  plt.legend()
```

In [30]:
```
plot_horsepower(x, y)
```



MLR

In [31]:
```
linear_model = tf.keras.Sequential([
    normalizer,
    layers.Dense(units=1)
])
```

In [32]:
```
linear_model.layers[1].kernel
```

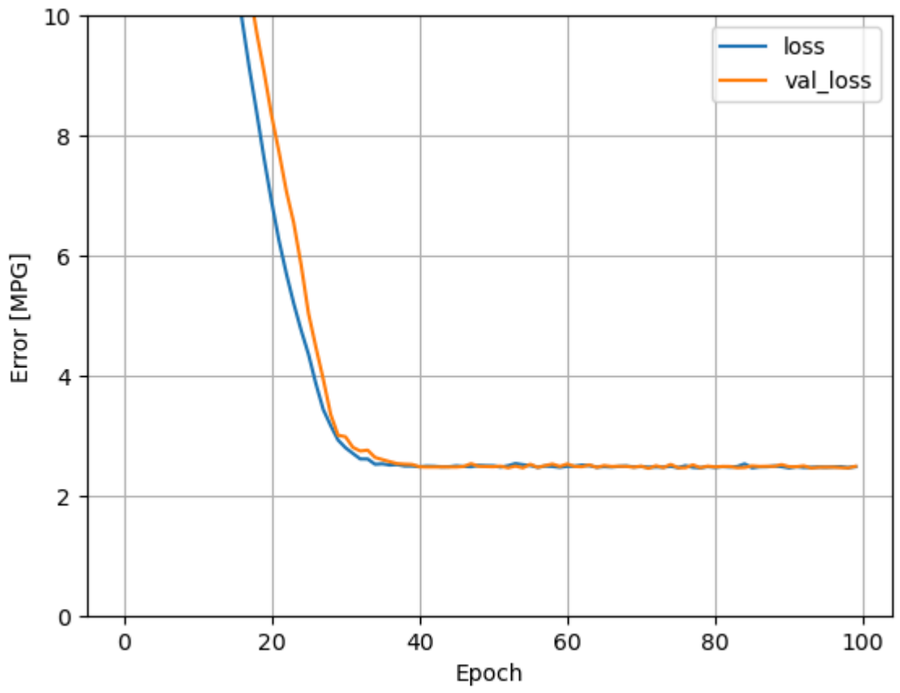
Out[32]:
```
<tf.Variable 'dense_1/kernel:0' shape=(9, 1) dtype=float32, numpy=
array([[-0.5449934 ],
       [ 0.08895987],
       [-0.11711317],
       [ 0.66201925],
       [ 0.3909036 ],
       [ 0.71676576],
       [ 0.57576394],
       [ 0.26156402],
       [ 0.7015773 ]], dtype=float32)>
```

In [33]:
```
linear_model.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate=0.1),
    loss='mean_absolute_error')
```

In [34]:
```
%%time
history = linear_model.fit(
    train_features,
    train_labels,
    epochs=100,
    verbose=0,
    validation_split = 0.2)
```

```
CPU times: total: 5.39 s
Wall time: 4.51 s
```

In [35]:
```
plot_loss(history)
```



In [36]:
```
test_results['linear_model'] = linear_model.evaluate(
    test_features, test_labels, verbose=0)
```

In [ ]:
```
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```