Your company has decided to produce \( P \) by the reaction \( A \rightarrow P \). Unfortunately, there is a parallel reaction, \( A \rightarrow X \). Both reactions are irreversible and both reactions are incomplete. Reactant \( A \) is available only as a mixture with inert impurity \( I \).

\( A, I, \) and \( P \) have identical boiling points; we obtain pure \( P \) with a liquid-solid separator. But the solids \( A, I, \) and \( X \) retain some liquid \( P \).

A generic process is shown below. To produce and sell product \( P \), you need only a reactor and a liquid-solid separator. You have three options for the \( A+I+P+X \) mixture in the liquid-solid separator bottoms stream: (1) you may discard the mixture by sending 100\% of the stream to the purge, or (2) you may recycle some of the mixture, for example, by purging 50\% and sending 50\% through the recycle, or (3) you may purchase a second separator to separate and sell by-product \( X \). If you wish to produce \( X \), the bypass plus purge must be less than 100\%.

There are two grades of reactant purity. Grade 1 mixture is high purity \( A \) and is expensive. Grade 2 mixture is modest purity \( A \) and is less expensive.

There are two types for the reactor. Reactor Type 1 has a high conversion of \( A \) but has modest selectivity for \( P \) over \( X \). Reactor Type 2 has a lower conversion of \( A \), but better selectivity for \( P \) over \( X \).

There are two types for the liquid-solid separator. Both types produce pure \( P \), but differ by the amount of \( P \) retained by the solids. Liquid-solid separator Type 1 recovers more \( P \). Liquid-solid separator Type 2 retains more \( P \) in the solids stream but is less expensive to operate.

Disposal of the purged stream requires special treatment and is expensive.